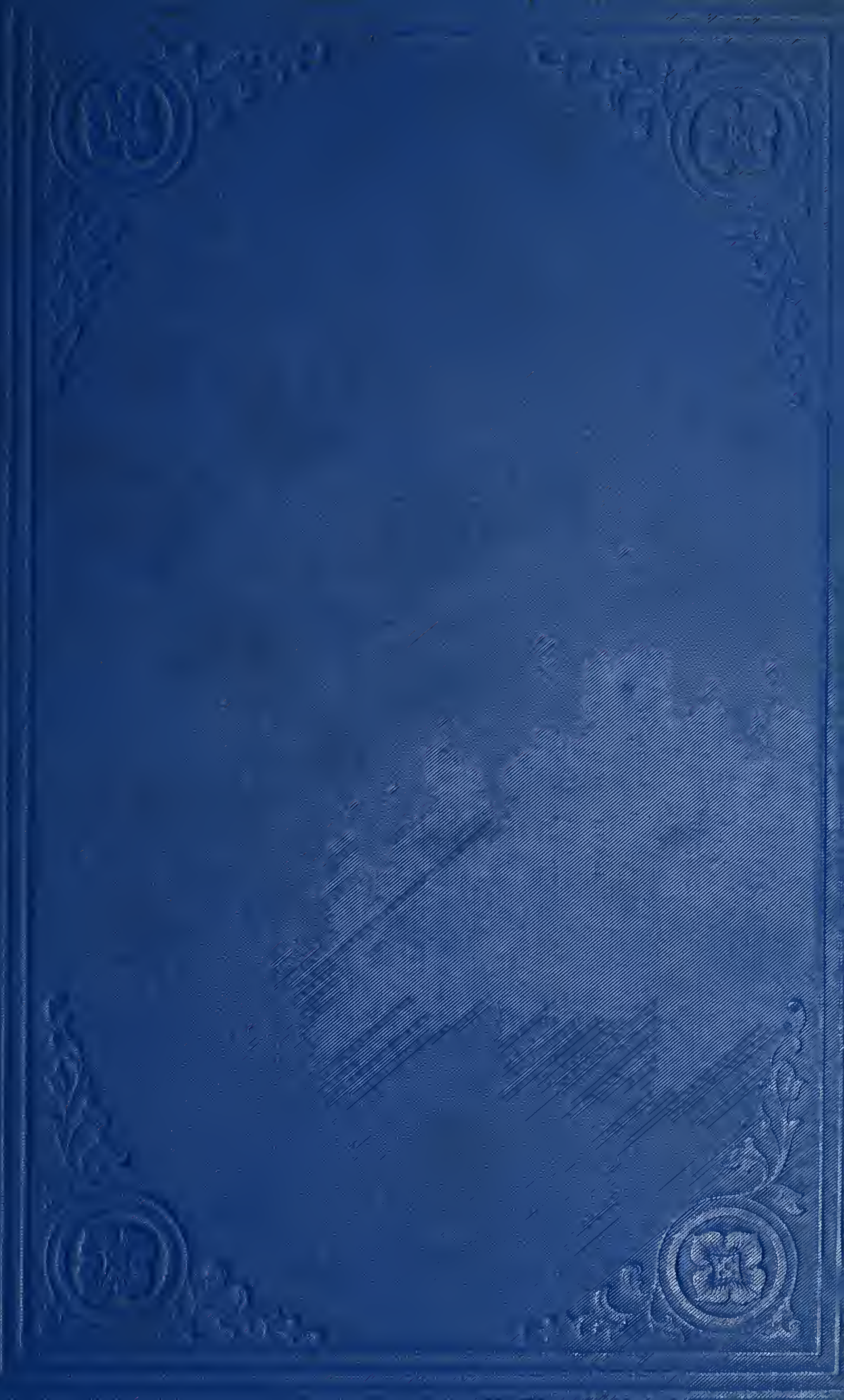

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Society
FOR THE
Promotion of Engineering Education

PROCEEDINGS
OF THE
NINETEENTH ANNUAL MEETING
HELD IN
PITTSBURGH, PA., JUNE 27, 28 AND 29, 1911

Volume XIX

EDITED BY
WILLIAM G. RAYMOND ARTHUR N. TALBOT
HENRY H. NORRIS

ITHACA, N. Y.
OFFICE OF THE SECRETARY
CORNELL UNIVERSITY
1912

PRESS OF
THE NEW ERA PRINTING COMPANY
LANCASTER, PA

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1911—1912

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CLARENCE A. WALDO, WILLIAM G. RAYMOND, 1907–8,
MORTIMER E. COOLEY, OLIN H. LANDRETH, 1908–9,
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William T. Magruder,
Clarence A. W. Waldo.
William G. Raymond,
Herman Schneider,

* Deceased.

DECEASED MEMBERS

Name.	Year of Election.	Date of Death.	Memoir. Vol. Page.
William A. Anthony	1907	May 29, 1908.	XVI, 409
George W. Atherton	1904	July 24, 1906.	XIV, 292
Volney G. Barbour	1894	June 4, 1901.	IX, 340
Charles B. Brush	1893	June 3, 1897.	VII, 181
Storm Bull	1893	November 18, 1907.	XVI, 407
Octave Chanute	1907	November 23, 1910.	XIX, 501
Eckley B. Coxe	1894	May 13, 1895.	VII, 182
Thomas M. Drown	1895	November 16, 1904.	XII, 244
Chas. B. Dudley	1894	December 21, 1909.	XVIII, 446
Francis R. Fava, Jr.	1894	March 28, 1896.	VII, 183
Estevan A. Fuertes	1894	January 16, 1903.	XI, 372
Henry Fulton	1894	December 6, 1901.	X, 258
Herbert G. Greer	1894	March 7, 1900.	VIII, 371
Thomas Gray	1895	December 19, 1908.	XVII, 238
Lyman Hall	1904	August 16, 1905.	XIV, 287
E. L. Hancock	1903	October 1, 1911.	XIX, 505
Albert H. Heller	1903	February 20, 1906.	XIV, 290
John B. Johnson	1893	June 23, 1902.	X, 259
J. W. Johnson	1907	August 29, 1911.	XIX, 506
Rodney G. Kimball	1894	April 25, 1900.	X, 261
Burton S. Lanphear	1897	October 14, 1904.	XII, 249
Benjamin F. La Rue	1893	December 22, 1903.	XII, 243
N. W. Lord	1907	May 23, 1911.	XIX, 507
C. S. Magowan	1896	November 14, 1907.	XVI, 406
Charles P. Matthews	1893	November 23, 1907.	XVI, 408
S. W. Robinson	1893	October 31, 1910.	XIX, 510
Justus M. Silliman	1894	April 15, 1896.	VII, 184
James H. Stanwood	1894	May 24, 1896.	VII, 185
Robert H. Thurston	1893	October 25, 1903.	XII, 246
Alphonse N. Van Daell	1897	March 28, 1899.	VII, 186
J. A. Veazey	1911	August 21, 1911.	XIX, 512
John R. Wagner	1894	January 21, 1899.	VII, 187
Francis A. Walker	1896	January 5, 1897.	VII, 188
Howard S. Webb	1897	June 12, 1905.	XIV, 286
Nelson O. Whitney	1893	March 17, 1901.	IX, 339
James R. Willett	1896	May 9, 1907.	XV, 679
De Volson Wood	1893	June 27, 1897.	V, 325

GEOGRAPHICAL SUMMARY OF MEMBERS.

Alabama	12
Arizona	1
Arkansas	6
California	18
Colorado	14
Connecticut	14
Delaware	4
District of Columbia	10
Florida	4
Georgia	2
Idaho	7
Illinois	89
Indiana	21
Iowa	25
Kansas	18
Kentucky	4
Louisiana	7
Maine	6
Maryland	5
Massachusetts	92
Michigan	46
Minnesota	29
Mississippi	5
Missouri	37
Montana	4
Nebraska	11
Nevada	1
New Hampshire	6
New Jersey	33
New Mexico	5
New York	160
North Carolina	5
North Dakota	6
Ohio	59
Oklahoma	1
Oregon	10
Pennsylvania	101
Rhode Island	9
South Carolina	2
South Dakota	6
Tennessee	6
Texas	14
Utah	12
Vermont	6
Virginia	8
Washington	15
West Virginia	5
Wisconsin	33
Wyoming	3
Australia	2
Brazil	2
British Columbia	1
Canada	18
Chile	2
China	3
England	3
Hawaii Territory	1
Hungary	1
India	1
Japan	3
Mexico	1
Panama	2
Philippine Islands	2
Russia	1
Total	1040

SUMMARY OF OCCUPATION.

Classification	Teachers			Practitioners		
	1909	1910	1911	1909	1910	1911
Architecture	4	6	7	0	1	1
Biology	1	8	1	0	0	0
Chemistry	10	21	16	1	0	0
Civil Engineering	160	172	144	22	67	82
Deans and Directors only	28	37	81	0	0	0
Drawing	42	41	54	0	3	2
Electrical Engineering	81	96	101	15	11	38
English	0	0	10	0	0	0
Journalists and Publishers	0	0	0	15	15	25
Landscape Architecture	1	1	1	0	0	0
Manual Training	4	1	5	0	0	0
Mathematics	63	78	77	1	0	0
Mechanical Engineering	117	144	124	27	32	48
Mechanics	25	41	41	0	0	0
Mining Engineering	28	24	26	4	4	5
Physics	36	47	47	0	0	0
Presidents	23	22	18	0	9	0
Railway Engineering	0	0	20	0	0	0
Shopwork	6	16	12	0	0	0
Trades-school	4	0	0	0	0	0
Unclassified	9	12	0	20	29	54
Professors who are also Deans	(54)	(55)	(46)			
Total	642	767	785	105	171	255

INSTITUTIONS REPRESENTED.

	Members		
	1909	1910	1911
Acadia University, Wolfville, Nova Scotia	0	0	1
Alabama Polytechnic Institute, Auburn, Ala.	6	7	7
Alabama, University of, Tuscaloosa, Ala.	1	4	5
Arizona, University of, Tucson, Ariz.	1	1	1
Arkansas, University of, Fayetteville, Ark.	5	6	6
Armour Institute of Technology, Chicago, Ill.	7	8	6
Bradley Polytechnic Institute, Peoria, Ill.	2	2	2
Brooklyn Manual Training H. S., Brooklyn, N. Y.	1	1	1
Brooklyn Polytechnic Institute, Brooklyn, N. Y.	4	7	7
Brown University, Providence, R. I.	7	8	7
Bucknell University, Lewisburg, Pa.	1	2	2
Buffalo Technical H. S., Buffalo, N. Y.	0	0	1
California, University of, Berkeley, Cal.	4	5	5
Carnegie Institution, Washington, D. C.	1	2	2
Carnegie Technical Schools, Pittsburgh, Pa.	7	13	13
Case School of Applied Science, Cleveland, O.	14	19	17
Casino Technical Night School, E. Pittsburgh, Pa.	0	1	1
Chestnut Hill Academy, Chestnut Hill, Pa.	0	1	1
Chicago, University of, Chicago, Ill.	1	1	2
Christian Brothers College, St. Louis, Mo.	0	0	1
Cincinnati, University of, Cincinnati, O.	6	7	6
Citadel, The, Charleston, S. C.	0	1	1
Clark College, Worcester, Mass.	2	2	2
Clarkson School of Technology, Potsdam, N. Y.	5	6	4
Clemson A. & M. College, Clemson College, S. C.	1	1	1
Cleveland Technical H. S., Cleveland, O.	1	1	1
Colorado College, Colorado Springs, Colo.	1	1	2
Colorado School of Mines, Golden, Colo.	1	1	1
Colorado State Agri. College, Fort Collins, Colo.	5	5	4
Colorado, University of, Boulder, Colo.	5	5	5
Columbia University, New York, N. Y.	11	13	13
Columbus Trades School, Columbus, O.	0	1	1
Cooper Union, New York, N. Y.	4	5	6
Cornell College, Mt. Vernon, Ia.	1	1	2
Cornell University, Ithaca, N. Y.	11	31	29
Cumberland University, Lebanon, Tenn.	0	0	1
Dartmouth College, Hanover, N. H.	3	5	4
Delaware College, Newark, Del.	2	3	3

Denison University, Granville, O.	1	1	1
Dorchester H. S., Dorchester Center, Mass.	1	1	1
Drexel Institute, Philadelphia, Pa.	5	4	4
Escola de Engenharia, Porto Alegre, Brazil	0	1	1
Florida, University of, Gainesville, Fla.	2	3	4
Franklin Institute, Philadelphia, Pa.	1	1	1
Franklin Union, Boston, Mass.	1	2	2
George Washington University, Washington, D. C.	3	2	2
Georgia School of Technology, Atlanta, Ga.	0	0	1
Goucher College, Baltimore, Md.	0	0	1
Harvard University, Cambridge, Mass.	11	16	15
Haverford College, Haverford, Pa.	1	1	1
Idaho, University of, Moscow, Ida.	1	3	5
Illinois, University of, Urbana, Ill.	26	35	42
Instituto Technico Professional, Porto Alegre, Brazil	1	1	1
International Correspondence Schools, Scranton, Pa.	2	1	2
Iowa State College, Ames, Ia.	10	11	13
Iowa, State University of, Iowa City, Ia.	5	8	7
Kansas City M. T. H. S., Kansas City, Mo.	1	1	1
Kansas State Agri. College, Manhattan, Kans.	5	10	8
Kansas, University of, Lawrence, Kans.	10	11	9
Kentucky, State University of, Lexington, Ky.	4	4	4
Lafayette College, Easton, Pa.	1	1	1
Lehigh University, South Bethlehem, Pa.	10	13	14
Leland Stanford Jr. Univ., Stanford Univ., Cal.	3	5	5
Lewis Institute, Chicago, Ill.	3	3	3
Louisiana State University, Baton Rouge, La.	2	3	3
Loyola University, Chicago, Ill.	0	0	1
McGill University, Montreal, Canada	2	3	3
McKinley High School, St. Louis, Mo.	1	1	1
McKinley High School, Washington, D. C.	0	1	1
Maine, University of, Orono, Me.	2	4	6
Manitoba, University of, Winnipeg, Man.	1	2	2
Marquette University, Milwaukee, Wis.	1	1	1
Massachusetts Agri. College, Amherst, Mass.	1	1	1
Massachusetts Inst. of Tech., Boston, Mass.	34	35	31
Michigan Agri. College, East Lansing, Mich.	11	13	19
Michigan College of Mines, Houghton, Mich.	6	7	7
Michigan, University of, Ann Arbor, Mich.	11	12	11
Millikin University, Jas., Decatur, Ill.	3	4	2
Minnesota, University of, Minneapolis, Minn.	20	23	28
Mississippi A. & M. College, Agricultural College, Miss.	1	2	4
Mississippi, University of, University, Miss.	3	3	1
Missouri School of Mines, Rolla, Mo.	0	2	3

Missouri, University of, Columbia, Mo.	10	13	11
Montana Agri. College, Bozeman, Mont.	1	2	2
Montana, University of, Missoula, Mont.	1	1	2
Nebraska, University of, Lincoln, Nebr.	6	10	11
Nevada, University of, Reno, Nev.	3	2	1
New Hampshire College, Durham, N. H.	2	2	2
New Mexico Agri. College, Agricultural College, N. M.	1	2	4
New York University, New York, N. Y.	4	4	4
North Carolina Agri. College, West Raleigh, N. C.	2	4	3
North Carolina, University of, Chapel Hill, N. C.	1	2	2
North Dakota Agri. College, Agricultural College, N. D.	1	2	2
North Dakota, University of, Grand Forks, N. D.	3	4	4
Northwestern University, Evanston, Ill.	4	4	4
Nova Scotia Technical College, Halifax, N. S.	1	2	3
Ohio Northern University, Ada, O.	1	2	2
Ohio State University, Columbus, O.	22	23	23
Oklahoma A. & M. College, Stillwater, Okla.	0	1	1
Oregon Agri. College, Corvallis, Ore.	1	1	3
Oregon, University of, Eugene, Ore.	1	1	3
Pasadena High School, Pasadena, Cal.	0	0	1
Pei Yang University, Tientsin, China	2	2	2
Pennsylvania College, Gettysburg, Pa.	0	0	1
Pennsylvania State College, State College, Pa.	16	15	14
Pennsylvania, University of, Philadelphia, Pa.	6	6	7
Philadelphia Central M. T. H. S., Philadelphia, Pa.	1	1	1
Pittsburgh Central H. S., Pittsburgh, Pa.	0	0	1
Pittsburgh, University of, Pittsburgh, Pa.	1	5	6
Pomona College, Claremont, Calif.	0	0	1
Pratt Institute, Brooklyn, N. Y.	17	18	14
Princeton University, Princeton, N. J.	2	2	2
Purdue University, Lafayette, Ind.	18	19	17
Queensland, University of, Brisbane, Australia	0	0	1
Rensselaer Polytechnic Institute, Troy, N. Y.	3	3	3
Rhode Island State College, Kingston, R. I.	0	0	1
Rose Polytechnic Institute, Terre Haute, Ind.	2	2	3
Rutgers College, New Brunswick, N. J.	5	7	6
Sheffield, University of, Sheffield, England	1	1	1
Southern California University, Los Angeles, Cal.	2	2	2
South Dakota State College, Brookings, S. D.	3	4	4
South Dakota, University of, Vermillion, S. D.	1	1	2
St. Petersburg, Polytech. Inst. of, St. Petersburg, Russia.	0	1	1
Stevens Institute of Technology, Hoboken, N. J.	14	14	12
Stuyvesant High School, New York City	0	0	1
Swarthmore College, Swarthmore, Pa.	1	1	1

Sydney, University of, Sydney, Australia	1	2	1
Syracuse University, Syracuse, N. Y.	2	3	2
Tennessee, University of, Knoxville, Tenn.	3	3	2
Texas A. & M. College, College Station, Tex.	6	5	8
Texas, University of, Austin, Tex.	3	5	3
Throop Polytechnic Institute, Pasadena, Cal.	1	1	2
Tokyo Imperial University, Tokyo, Japan	0	1	1
Toronto, University of, Toronto, Canada	4	4	6
Tufts College, Tufts College, Mass.	9	9	10
Tulane University, New Orleans, La.	4	3	3
Union University, Schenectady, N. Y.	9	8	6
United States Naval Academy, Annapolis, Md.	1	1	1
Utah, University of, Salt Lake City, Utah	2	3	9
Valparaiso University, Valparaiso, Ind.	1	1	1
Vanderbilt University, Nashville, Tenn.	1	1	1
Vermont, University of, Burlington, Vt.	6	5	6
Virginia Military Institute, Lexington, Va.	1	1	2
Virginia Polytechnic Institute, Blacksburg, Va.	2	4	5
Washington & Lee University, Lexington, Va.	1	1	1
Washington State College, Pullman, Wash.	0	0	1
Washington University, St. Louis, Mo.	7	8	9
Washington, University of, Seattle, Wash.	7	8	8
Wentworth Institute, Boston, Mass.	0	1	2
West Virginia University, Morgantown, W. Va.	5	8	5
Whitman College, Walla Walla, Wash.	1	1	3
Williamson Free School, Williamson School, Pa.	2	2	2
Wisconsin, University of, Madison, Wis.	24	28	27
Worcester Polytechnic Institute, Worcester, Mass.	13	17	11
Wyoming, University of, Laramie, Wyo.	0	1	2
Yale University, New Haven, Conn.	13	14	14

GENERAL SUMMARY.

DIFFERENT INSTITUTIONS REPRESENTED.

Colleges and Universities teaching Engineering	1909	1910	1911
Domestic	126	121	137
Foreign	9	12	12
Manual Training, High, Correspondence, and Trade Schools	9	13	16
Total Institutions	144	146	165
Teachers, and, in many cases, also practitioners	642	767	787
Practitioners, not teaching	105	171	253
Total Members	747	938	1040

CONSTITUTION

OF THE

Society for the Promotion of Engineering Education

1. Name—This organization shall be called the Society for the Promotion of Engineering Education.

2. Members—Members of the Society shall be those persons who occupy or have occupied responsible positions in the work of engineering instruction, together with engineering practitioners and other persons interested in engineering education.

Honorary Members of the Society shall be such persons as may be recommended by unanimous vote of the Council after a letter ballot. In taking this ballot, the Secretary is directed to close the polls one month after the names of the candidates are sent out. Councilors not heard from will be counted in favor of the candidate. Honorary Members shall not have the right to vote, shall not be eligible to office, and shall not be required to pay any fees or dues.

Any Member not in arrears for dues may become a Life Member by paying Fifty Dollars into the Treasury of the Society at one time.

The name of each candidate for membership shall be proposed in writing to the Council by two members by whom he is personally known. Such name, if approved by the Council, shall be voted on by the Society at the annual meeting, a vote of three-fourths of those present being required to elect; or, during the period between annual meetings, an affirmative letter ballot of three-fourths of those members of the Council whose vote reaches the Secretary within one month from the time of sending out the name of the candidate shall elect. Such letter ballot elections shall be credited to the previous annual meeting and dues will date from that time.

3. OFFICERS—There shall be a President, two Vice-Presidents, a Secretary and a Treasurer, each to hold office for one year, or until their successors have been elected and have qualified. The Officers shall be elected by ballot of the Society at the annual meeting.

4. COUNCIL—The Council of this Society shall consist of twenty-one elective members, one-third of whom shall retire annually. The Officers and the Past Presidents of the Society shall be members of the Council *ex-officiis.*

Any member of this Society shall be eligible to election to the Council, provided that not more than one elective member shall be from any one college.

Members of the Council shall be elected by ballot by the Society at its annual meeting.

The Council shall constitute a general executive body of the Society, pass on proposals for membership, elect candidates *ad interim,* attend to all business of the Society, receive and report on propositions for amendments to the constitution, and shall have power to fill temporary vacancies in the offices.

The President of the Society shall be Chairman of the Council, and the Secretary of the Society shall be Secretary of the Council and shall keep the minutes of its meetings and an accurate record of all its actions.

When votes taken by letter ballot of the Council shall be required, all votes which reach the Secretary within one month from the time of sending out the ballots shall be counted, but votes reaching the Secretary later than the time here specified shall not be counted.

5. NOMINATING COMMITTEE—The Nominating Committee shall consist of the Past Presidents and the seven elective members of the Council retiring the following year, provided, however, that if, of this committee, the number in attendance at any meeting be less than five, the President shall make appointments so as to form a committee of five.

6. FEES AND DUES—The admission fee, which shall also include the first year's dues, shall be *Four Dollars* (*$4.00*), and the annual dues thereafter *Four Dollars* (*$4.00*), pay-

able at the time of the annual meeting. The fiscal year shall end with the opening of the first General Session of the Annual Meeting. Those in arrears more than one year shall not be entitled to vote, nor to receive copies of the PROCEEDINGS, and such members shall be notified thereof by the Secretary one month previous to the annual meeting. Any member who has been in arrears more than two years and duly notified by the Secretary, shall be dropped from the roll, until such arrearages are paid.

7. MEETINGS—There shall be a regular meeting occurring at the time and place of the meeting of the American Association for the Advancement of Science, or of some one of the Nation Engineering Societies, or otherwise as the Council may determine.

8. PUBLICATIONS—The Proceedings of the Society, and such papers or abstracts as may be approved by the Council, shall be published as soon as possible after each annual meeting.

9. AMENDMENTS—This Constitution may be amended by a two-thirds vote of those present at any regular meeting of the Society provided the Amendment shall have been approved by a two-thirds vote of the Council taken by letter ballot.

BY-LAWS OF THE SOCIETY AND RULES GOVERNING THE COUNCIL.

First. The Officers of the Society shall constitute a Committee to arrange for the annual meeting and to prepare a program for the same.

Second. The President, the Secretary and the Treasurer shall constitute an Executive Committee which shall have charge of all matters relating to the expenditure of money of the Society, the making of appropriations for Committees and other purposes, the making of contracts, the approval of bills, and also during the period between the meetings of the Council shall have charge of other business affairs of the Society.

Third. Expenditures of money may be made only in accordance with a definite appropriation or direct vote of the

Executive Committee and bills shall not be paid by the Treasurer until they have been approved by all members of the Executive Committee.

Fourth. Reading of papers shall be limited to fifteen minutes each or to such other time as may be designated by the Program Committee, and abstracts of papers of about three hundred words shall be printed when practicable, and distributed in advance to the members.

Fifth. The time occupied by each person in the discussion of any paper shall not exceed five minutes.

Sixth. The President, the Secretary and the retiring Secretary shall constitute a Publication Committee, of which the Secretary shall be Chairman, to edit and have charge of the publication of the PROCEEDINGS of the Society, *except the volume of Proceedings of the last convention, which shall be edited by the retiring Secretary.* If at any time there be no retiring Secretary the retiring President shall be a member of this Committee.

Seventh. Additions or amendments may be made to these By-Laws on recommendation of the Council by a two-thirds affirmative vote at any regular meeting of the Society.

PUBLICATIONS.

The publications of the Society can be obtained from the Secretary. The current issues are distributed gratuitously to members in good standing. The price of the bound volumes of the Proceedings is $2.50 to non-members, $2.00 to public libraries, and $1.50 to members for their own libraries.

The BULLETIN is issued monthly from September to June. The price to non-members is *$3.00* per year. Libraries may order the BULLETIN and the PROCEEDINGS at *$4.00* per year, if the two are ordered together.

Reprints of papers may be ordered when the paper is in type form, and either with or without covers, at a price depending upon the number of pages and copies desired.

Italics in the above indicate changes made during the past year.

PROCEEDINGS.

PITTSBURGH MEETING.

JUNE 27 TO JUNE 29, 1911.

The nineteenth annual meeting of the Society for the Promotion of Engineering Education was held at the Carnegie Technical Schools and the University of Pittsburgh, Pittsburgh, Pa., on Tuesday, Wednesday and Thursday, June 27, 28 and 29, 1911. The meetings were held in the buildings of the Schools of Applied Science and Applied Industries of the Carnegie Technical Schools and in Thaw Hall of the University of Pittsburgh.

TUESDAY, JUNE 27.

Morning Session.

The meeting was called to order at 10:00 a. m. by President Arthur N. Talbot, Professor of Municipal and Sanitary Engineering, University of Illinois. The meeting was opened by an address of welcome from Director Arthur A. Hamerschlag, of the Carnegie Technical Schools. This address was responded to by President Talbot.

The first paper of the meeting, "Teaching English in Technical Schools," by Professor S. C. Earle, Tufts College, was presented by Dean G. C. Anthony of Tufts College. Following this Professor F. N. Raymond, of the University of Kansas, abstracted his paper on "The Preparation of Written Papers in Engineering Schools." The two papers, being in a similar field, were discussed together. The discussion showed great

Library
N. C. State College

interest in the subject. The President, Mr. Kent, Mr. Gehring, Professors Jacoby, Telleen, Hibbard, Flather, Tracy, Young, Magruder and Raymond, and Dean Anthony took part in the discussion.

Professor H. Wade Hibbard abstracted a paper by Professor H. S. Philbrick and himself, entitled "The Teaching of Scientific Shop Management, with the Use of Engineering School Shops as the Laboratory." They opened up a new field for study by the Society. An animated discussion by Professors Kunze, Hibbard, Wood, Mr. Kent and Director Williston followed the reading of the paper. Professor A. H. Blanchard then read his paper on "Graduate Courses in Highway Engineering at Columbia University."

At the close of the morning session a representative of the Conventions Bureau of St. Louis presented an invitation from that body for the Society to meet in St. Louis in 1912. The invitation was informally referred to the incoming Council for attention. Mimeographed copies of the reports of the Treasurer and the Secretary were distributed so that they might be studied in advance of their formal presentation.

Afternoon Session.

The larger portion of the afternoon session was taken up with a consideration of the report of the Committee on the Teaching of Mathematics to Engineering Students. This report had been printed in full in the BULLETIN during the year so that the members of the Society had had ample time to study it. After long discussion the following motions were passed: (1) That the Society accept the report and that the syllabi be printed in the Proceedings of the Society after the Committee has made such additions and modifications as they desire in view of the discussion at the meeting; and (2) that the Committee be requested to bring in a report covering the subjects of dynamics and numerical calculations at the next meeting. The hope was expressed that this report might appear in the BULLETIN in advance of the 1912 meeting.

Dean C. H. Benjamin's paper "The Balance of Courses in Chemical Engineering" was read in full by the Secretary and discussed by the President, Dean Bishop, and Professors Wood, Morse and Miller. A paper by Professor J. H. James, of the Carnegie Technical Schools, entitled "Chemical Education for the Industries" was then read by title.

Evening Session.

In the evening after the dinner at the Country Club, tendered to the Society by Director A. A. Hamerschlag on behalf of the Carnegie Technical Schools, President Talbot delivered his presidential address on the subject "The Engineering Teacher and his Preparation."

WEDNESDAY, JUNE 28.

Morning Session.

In accordance with the instructions of the Council the Secretary announced that at the evening session the question of raising the dues to $4.00 per year would come up for discussion and settlement. After a thorough study of the matter during the year the Program Committee had recommended that it is advisable to continue the publication of the BULLETIN and that it seems practicable to do so by an increase in the dues.

Chairman J. J. Flather, of the Committee on Entrance Requirements, presented an abstract of the report of the Committee, which had appeared in the BULLETIN. He stated that the report is essentially the same as that presented at the Madison meeting with the exception of the requirements in mathematics. He stated farther that the members of the Committee wished the report to be considered a final one and that they desired to be discharged. After a very full discussion of the report the following motion was passed: That the report of the Committee be accepted with the thanks of the Society and that the Committee be discharged. It was the sense of the meeting that the Committee has the right to make slight modifications in the report before it is printed in the *Proceedings* if they so desire. As the Committee on Entrance Requirements is a standing one, President Talbot called attention to the fact that the incoming administration would appoint a new committee.

At this point in the session President Talbot announced as the Committee on Resolutions, Professors J. C. Tracy, H. S. Jacoby and E. C. Schmidt; and as the Auditing Committee, Professors A. J. Wood, J. E. Boyd and J. P. Spalding. He also called attention to the fact that the Nominating Committee consists of the past-presidents of the Society and of those members of the Council whose terms of office expire at the next meeting.

After the above announcements, Mr. H. A. Gehring, of the staff of the New York State Engineer, read a paper on "The Use of Logarithmic Diagrams in Laboratory Work." The members present agreed with the speaker as to the importance of checking results as laboratory work proceeds. Professor J. M. White, of the University of Illinois then read his paper on "The Architecture of Engineering Schools."

After the morning session an opportunity was afforded for the members to make a brief inspection of the buildings of the Carnegie Technical Schools.

Evening Session.

The evening session was held in the main lecture room of the School of Applied Industries of the Carnegie Technical Schools. An executive session was first on the program. The Council made a number of recommendations which were acted upon as follows:

1. That a list of forty-two applicants, approved at the morning meeting of the Council, be elected. The Secretary was instructed to cast a unanimous favorable ballot for the Society, which he did.

2. That the dues of the Society be increased to four dollars per year, this recommendation having been made by the Program Committee and approved by the Council by letter ballot more than thirty days in advance of the meeting. The recommendation was unanimously approved by the Society.

3. That the BULLETIN be continued and established as a permanent institution. This was unanimously adopted.

4. That the By-laws be amended as follows: Add to line 4, article 6 "except the volume of the *Proceedings* of the last convention, which shall be edited by the retiring Secretary." After explanation by the President that the purpose of the by-laws is to make it the duty of the retiring Secretary to edit the proceedings of the meeting which he had organized and with which he, therefore, was most familiar, the amendment was unanimously adopted.

5. That, in view of the difficulty of doing justice to the enormous number of technical books, it is deemed inexpedient to publish the report of the Committee on Technical Books for Libraries. This recommendation was adopted after explanation that the recommendation of the Council was made after the presentation of a report to the same effect from the Program Committee which had given careful study to the matter during the year.

The reports of the Treasurer and the Secretary were next presented. As these had been distributed in mimeograph form they were not read. The reports were accepted by the Society with a vote of thanks for the efforts of all of the officers to make the work of the Society a success during the past year. The Auditing Committee, consisting of Professors A. J. Wood, J. P. Spalding and J. E. Boyd, then reported that they had examined the Treasurer's records and vouchers and that these had been found to be correct.

Mr. Kent suggested that as the finances of the Society seem to warrant it, in the future all papers should be printed in advance of the meeting so that the members can have an opportunity to study them carefully. In this case it would not be necessary to consume more than, say, five minutes in the presentation of an abstract at the meeting. Professor Jacoby endorsed this suggestion and stated that the members should be able to expect the Program Committee to set a date on which the manuscripts of papers shall be in hand, giving the right of way at the meetings to papers which have been printed in advance. Provision should be made for papers which come in late but it should be understood that these will have only such consideration as can be given them after the other papers have been considered.

Professor Magruder raised a question as to the proper time of the year at which the meetings of the Society should be held. A number of members spoke informally, "pro and con," as to the desirability of holding winter meetings. An informal ballot showed a strong preference among those present for a continuance of the present practice of holding meetings in the early summer.

The Nominating Committee made the following report, signed by Professor C. L. Crandall as chairman:

The Nominating Committee nominates the following members for the respective offices for the ensuing year.

For President: W. G. Raymond, University of Iowa.

For Vice-presidents: G. C. Anthony, Tufts College, and Frank B. Gilbreth, New York City.

For Members of Council: J. E. Boyd, Ohio State University; C. E. Crouch, University of North Dakota; C. E. Magnusson, University of Washington; H. H. Stoek, University of Illinois; J. A. L. Waddell, Kansas City; A. J. Wood, Pennsylvania State College.

For Secretary: H. H. Norris, Cornell University.

For Treasurer: W. O. Wiley, New York City.

After passing a motion that the nominations be closed, the Society instructed the President to cast a ballot for the nominees named by the Committee, which was done.

The balance of the evening session was devoted to the presentation and discussion of two papers, "The Wentworth Institute'' by Director A. L. Williston, and ''The College Campus,'' by Professor J. M. White. The former was illustrated by charts and the latter by lantern slides. A number of interesting features of college campuses and buildings were brought out in the discussion, particularly the relation of the architect to the faculty in the planning and construction of buildings. Another was the location of the library building on the campus with a view to increasing the use of books by making the building accessible. These and other topics were vigorously discussed until a late hour. After the President had invited the newly-elected members of the Council to meet with the 1910–1911 Council the next morning the meeting adjourned.

THURSDAY, JUNE 29.

Morning Session.

The meeting was called to order at 9:30 by Vice-president Kent, who at the invitation of the President presided at the session. The meeting was held in Thaw Hall of the University of Pittsburgh and Chancellor S. B. McCormick, of the University, welcomed the Society to the University. He explained somewhat of the history of the University and of its relation to the other educational institutions of the vicinity. Vice-president Kent responded to the Chancellor's words of welcome.

Professor S. B. Charters, of the Leland Stanford, Jr., University, abstracted a paper prepared by Professor W. A. Hillebrand and himself on ''An Engineering Course for Underclassmen.'' This was followed by a paper on ''Electrical Engineering Instruction '' prepared and presented by Professor E. B. Paine, of the University of Illinois. Dean W. G. Raymond's paper entitled ''All-year Sessions: Individual Instruction: Renewed Suggestions,'' which had been printed in full on the program, was received by title. These three papers were discussed briefly.

The concluding papers of the session and of the convention were of a similar nature and they were therefore grouped together for presentation and discussion. These were: ''Technical Training from the Business Man's Standpoint,'' by Mr. E. B. Raymond, Vice-president of the Pittsburgh Plate Glass Company; ''Adapting Technical Graduates to the Industries,'' by Messrs. C. F. Scott and C. R. Dooley, of the Westinghouse Electric and Manufacturing Company; and ''The Coöperative System of Engineering Education at the University of Pittsburgh,'' by Dean F. L. Bishop. The Society then proceeded to discuss the qualities of technical students and graduates.

The President then took the chair and called for the report of the Committee on Resolutions. The following report was presented and adopted:

''The visit of the Society to Pittsburgh has been made pleasant to its members by the many courtesies and opportunities for enjoyment offered by those who have so generously assumed the responsibility for this entertainment. The Society appreciates the thoughtfulness and kindness which have been shown in so many ways, and it desires to record this appreciation. Therefore,

''*Be it Resolved,* that the thanks of the Society be hereby tendered to the Administrations and Faculties of the Carnegie Technical Schools and the University of Pittsburgh for providing places of meeting and for their hospitable care and entertainment; to the manufacturing firms of Pittsburgh and the vicinity who have contributed so much of pleasure and profit to the Society by opening their works for inspection; to the local committee to whose efforts and zeal so much of the success of the convention is due; and to all others who in any way have acted as hosts to the members of the Society and to the ladies who have accompanied them.''

(Signed) Henry S. Jacoby,
Edward C. Schmidt,
J. C. Tracy,
Committee.

SOCIAL FEATURES OF THE CONVENTION.

In planning the program of entertainment, the local committe arranged for every possible opportunity for the members to get together for informal discussion. At noon on Tuesday and Wednesday buffet luncheons were served in the Margaret Carnegie School for Women, conveniently located with respect to the convention building. An ample allowance of time for the luncheon was made and this was utilized by the members in renewing old acquaintances and forming new ones. Following the Tuesday afternoon session the members went by car and automobile to the Country Club where they had the opportunity of meeting the ladies of the faculties of the Carnegie Technical Schools and the University of Pittsburgh, and several of the trustees with their wives. After a social hour in ideal surroundings the members and other guests enjoyed a delightful dinner tendered by Director A. A. Hamerschlag on behalf of the Carnegie Technical Schools. The only after-dinner speeches were a short one by Director Hamerschlag and the presidential address of Professor A. N. Talbot.

On Thursday, following the morning session, the University of Pittsburgh, with Chancellor S. B. McCormick as host, entertained the members at luncheon at the University Club. On Thursday evening an informal reception was held in the foyer of the Carnegie Music Hall. Here an opportunity was afforded for the local alumni of the various colleges to meet their former teachers. Large placards marked the rallying places for a number of the colleges and each man present was tagged with the names of all of the educational institutions with which he had been connected. After the reception a brief program was given on the great organ and a few remarks were made by the famous lens maker, Mr. Brashear, The members then visited the museum and picture gallery of the Institute.

During the sessions the ladies of the convention were entertained by the local ladies with receptions and automobile rides.

EXCURSIONS TO INDUSTRIAL PLANTS.

As the convention was held in the heart of the industrial district the local committee made the most of the opportunity to show the visitors the manufacturing wonders of the neighborhood. Wednesday and Thursday afternoons were devoted to these excursions and a number of members remained after the convention for additional trips at the invitation of the committee. The value of the inspection trips was enhanced by a handsome hand-book which the local committee prepared and distributed to every member of the Society, whether he expected to attend the meeting or not. This was done without expense to the Society. The book was well illustrated and contained descriptions of all the important manufacturing plants in the vicinity.

For the tireless efforts of the local committee to make the meeting a success the thanks of the Society are due. The committee consisted of Dean J. H. Leete, chairman, Mr. C. F. Scott, Deans C. B. Connelley and F. L. Bishop, and Professor W. E. Mott.

ATTENDANCE AT THE CONVENTION.

One hundred and nineteen members and guests registered at the meeting, a number considerably smaller than were in attendance last year. This shrinkage may be attributed to the fact that other important conventions were in session at the same time. It had been found impracticable to avoid conflicts but it is hoped that by another year arrangements can be made with other societies by which such conflicts may be minimized.

The names registered are as follows: M. W. Alexander, G. C. Anthony, H. T. R. Aude, E. E. Bankson, Frederic Bass, H. M. Biebel, F. L. Bishop, A. H. Blanchard, J. E. Boyd, J. N. Bradford, A. M. Buck, F. E. Burpee, H. A. Calderwood, T. L. Cannon, R. A. Caughey, S. B. Charters, jr., J. J. Clark, E. F. Coddington, C. B. Connelley, C. L. Crandall, W. R. Crane, C. H. Crouch, H. B. Dates, C. R. Dooley, C. E. Downton, W. H. Dosey, W. W. Dunkin, P. M. Dysart, C. R.

Eastman, F. L. Emory, D. D. Ewing, J. J. Flather, M. M. Foss, T. E. French, A. E. Frost, H. A. Gehring, Edward Godfrey, C. O. Gunther, A. A. Hamerschlag, P. W. Hepburn, H. Wade Hibbard, H. H. Higbie, J. W. Hughes, J. A. Hunter, J. P. Jackson, H. S. Jacoby, Mrs. Jacoby, J. H. James, A. W. Kelly, Morris Knowles, Wm. Kent, A. M. Kenyon, Albert Kingsbury, E. J. Kunze, Mrs. Kunze, V. E. Laknosky, J. H. Leete, S. B. Linhart, S. B. McCormick, F. M. McCullough, F. F. McIntosh, W. T. Magruder, Anson Marston, E. R. Maurer, C. L. Mees, H. B. Meller, E. E. Mercer, Hugh Miller, J. T. Morris, G. H. Morse, J. L. Morse, W. E. Mott, J. H. Nelson, H. H. Norris, Frank Orbin, E. B. Paine, Earl Querbach, F. N. Raymond, N. C. Riggs, S. R. Rhodes, W. J. Risley, Ralph Rogers, A. B. Sage, H. E. Satterfield, J. A. Schaeffer, E. C. Schmidt, W. H. Schuerman, P. K. Slaymaker, H. E. Smith, J. H. Smith, L. B. Smith, F. P. Spalding, R. F. Stewart, H. H. Stoek, T. L. Sturges, jr., A. N. Talbot, Mrs. Talbot, J. M. Telleen, H. R. Thayer, G. L. Thomas, J. S. Thompson, J. C. Tracy, C. L. W. Trinks, F. E. Turneaure, M. E. Wadsworth, F. C. Wagner, R. J. Watson, J. B. Webb, John Weber, C. N. Wenrick, A. L. Westcott, J. M. White, W. O. Wiley, A. L. Williston, A. J. Wood, Mrs. Wood, W. R. Work, A. J. Wurts, C. M. Young.

MINUTES OF THE COUNCIL MEETINGS AT PITTSBURGH.

First Session, June 28.

The meeting was called to order at 9:00 a. m. by President Talbot with the following members present: Crandall, Hibbard, Leete, Magruder, Maurer, Norris, Talbot, Turneaure and Wiley.

A list of 42 applicants was recommended to the Society for election, as follows: M. W. Alexander, C. E. Ard, E. A. Averill, C. C. Bishop, R. A. Caughey, E. F. Coddington, Geo. A. Damon, C. H. Davis, V. Y. Davoud, A. D. DuBois, E. J. Edwards, S. P. Farwell, F. W. Frost, F. B. Gilbreth, A. H. Goldingham, A. C. Harper, H. E. T. Haultain, G. G. Hitchcock, Sentaro Kondo, Brother Hubert Lewis, E. H. McAlister, R. S. McCaffery, Ben McCrum, S. C. McMeen, William Maver Jr., Gaston Ossa, A. L. Rohrer, S. R. Schealer, L. B. Selby, J. M. Smith, O. L. Snow, J. B. Swinney, Jas. Thompson, F. P. Valentine, J. A. Veazey, F. L. O. Wadsworth, F. C. Wagner, S. T. Wagner, E. H. Waldo, O. L. Waller, C. W. Watts, J. P. J. Williams.

It was voted to recommend to the Society the increase of the dues to $4.00 to permit the continuation of the BULLETIN and the Secretary was instructed to make an announcement to this effect to the Society preliminary to the executive session of the Society.

The Treasurer was authorized to expend a sum not to exceed $200 for the opening of a set of double-entry books, this sum to include the honorarium of the Treasurer's assistant for the year 1911–1912.

It was voted to recommend to the Society the continuation of the BULLETIN and its establishment as a permanent institution.

On motion of Professor Magruder it was voted to recommend to the Society the addition to line 4, article 6, of the By-Laws the following: "except the volume of the *Proceedings* of the last convention, which shall be edited by the retiring secretary."

The Council received the report of the Program Committee to the effect that in the unanimous opinion of the Committee it is inexpedient to print the report of the Committee on Technical Books for Libraries, as it is practically impossible to do justice to the enormous number of technical books on the market.

Second Session, June 29.

President Talbot called the meeting to order at 9:00 a. m., with the following members present (the list includes members of the new Council): Messrs. Emory, Kent, Magruder, Norris, Talbot and Wood.

Letters were read from officials of Atlantic City, Niagara Falls, St. Louis, and Chicago, inviting the Society to meet at these respective cities next summer.

The Council voted to recommend to the incoming Council the city of Boston for the next meeting, provided that, for special reasons, some other city does not prove more suitable.

Resignations were accepted from Messrs. J. H. Barr and J. B. Stanwood.

On motion of Professor Magruder the standing committee on statistics was discharged and a new one ordered.

A letter from Dean A. H. Fuller concerning certain statistics of sizes of sections, duties of instructors, etc., was referred to the Committee on Statistics.

The Secretary was instructed to ascertain the status of the work of the Joint Committee on Engineering Education.

HENRY H. NORRIS,
Secretary.

SECRETARY'S REPORT, 1910–1911.

To the Society for the Promotion of Engineering Education:

The work of the Secretary's department during the past year has comprised the following divisions:

a. Editing the Proceedings of the Society.

b. Publishing the Proceedings.

c. Maintaining a correct roll of members with addresses and publishing the same.

d. Conducting a continuous membership campaign.

e. Editing the Bulletin.

f. Publishing the Bulletin.

g. Miscellaneous correspondence.

h. Filing and arranging the Society's records.

PROCEEDINGS.

With the sanction of the Council the membership list was omitted from the Proceedings this year and the size of the volume was thus kept down. In addition the weight of paper was reduced for the same purpose. The size of type had been reduced the previous year. As a result the volume has been kept of convenient size although the amount of material contained is much greater than that of any preceding, except 1907. Many valuable contributions to the discussion were obtained after the meeting by means of the publication of papers in the Bulletin.

The publication of the Proceedings involved, among other items, an advertising campaign. All of the important libraries, about 1,100 in number, were notified of the appearance of the volume and a number of copies were sold. The sale of back volumes to members and others also was continued and with the sale of the current volume to outsiders formed a satisfactory source of income. In spite of the large sale, however, the total stock is much larger than last year. A large stock has been kept at the Secretary's office, but the main storage is at the printer's at Lancaster, Pa. The stock is fully insured.

Membership.

The gross increase of membership during the year has amounted to 211 (see appendix) exclusive of a long list of applications to be acted upon at the meeting. A very small number of resignations were received, but the Council will be obliged to drop a score or more for nonpayment of dues. The Secretary has been assisted in this work by a large membership committee with representatives from several different professions. Several members of the committee have rendered much assistance. By means of form and personal letters several thousand persons have been invited to join during the year. The membership passed the "1,000-mark" about March 1st. A number of members not on the membership committee have sent in applications. Their help has been greatly appreciated.

Bulletin.

The editorial work has consisted in securing news of the colleges, in arranging the papers for publication, etc. A number of members agreed to act as correspondents and these have sent in numerous interesting news and other items.

The publication work has been greater than the editorial. Securing advertising support has presented some difficulties as advertisers are wary regarding new publications. Several advertisers, however, have stood by loyally and others are taking hold. Tables showing the record of the year's advertising are given in an appendix.

Other Matters.

During the year the various records of the Society have been gone over and all useless matter eliminated. An accession list of members from the beginning has been prepared with as accurate a record of withdrawals as it has been possible to make. Sectional filing cabinets of modern design have been procured and the property of the Society has been arranged for ready reference. A large room at the Secretary's residence has been fitted up for the Society's use and a stenographer is continuously employed in the many activities of the Society.

The correspondence involves the keeping in touch with other societies and the press, the arranging of details for the program and other committees, etc.

Respectfully submitted,
HENRY H. NORRIS,
Secretary.

APPENDIX TO SECRETARY'S REPORT.

NEW MEMBERS.

Elected by letter ballot, September 1, 1910: M. A. de Chatelain, R. H. Fisher, Frank Koester. (3.)

Elected by letter ballot, October 30, 1910: L. E. Akeley, W. E. Barlow, P. L. Beam, J. A. Bensel, W. H. Breithaupt, A. M. Buck, C. S. Burns, H. J. Burt, I. P. Church, W. W. Colpitts, M. L. Cooke, P. H. Daggett, E. A. Gibbs, A. J. Gibson, Henry Goldmark, J. C. Hallsted, L. A. Hazeltine, W. O. Henderer, E. G. Hoefer, R. P. Iyer, E. S. Jarrett, Phelps Johnson, J. E. Kaulfuss, H. G. Kelley, H. H. McClintic, D. W. McNaugher, Leonard Metcalf, J. C. Ralston, W. H. Rasche, H. A. Sayre, J. D. Schuyler, H. W. Smith, J. F. Stevens, G. W. Stewart, Gustav Wittig, P. L. Wolfel, S. M. Woodward. (37.)

Elected by letter ballot, November 25, 1910: F. L. Bixby, J. N. Bryant, W. H. Burger, W. L. Church, W. W. Curtis, N. B. Garver, M. W. Haskell, H. C. Kendall, F. W. Marquis, C. E. Noerenberg, G. W. Pickels, Jr., J. N. Vedder, O. E. Williams. (13.)

Elected by letter ballot, November 30, 1910: A. A. Adler, Wm. W. Bird, Geo. L. Brown, L. W. Chase, E. F. Church, Jr., Enrique Cruchaga Ossa, F. M. Dawson, L. M. Dennis, J. F. H. Douglas, R. J. Fogg, F. S. Foote, Sr., H. W. Heidenger, J. C. Hubbard, Chas. Jablow, A. J. Jobson, A. R. Keller, J. A. Lahmer, J. F. LeBaron, Jacob Lund, Jas. C. Lund, F. C. Miller, H. E. Murdock, F. Y. Parker, W. S. Payne, J. E. Rasmusen, J. J. Richey, F. K. Richtmyer, A. A. Robinson, L. A. Scipio, E. C. Shankland, P. K. Slaymaker, J. E. Smith, R. K. Steward, Chas. L. Walker, A. E. White, Paul Willis, H. C. Woods. (37.)

Elected by letter ballot, December 13, 1910: G. G. Anderson, G. F. Blessing, A. W. Browne, J. T. Buser, T. C. du Pont, Isami Hiroi, H. E. Marsh, F. A. Molby, Richard Morris, J. L. Morse, J. C. Parker. G. C. Priester, A. C. Prime, D. B. Steinman, S. A. Stephenson, Jr., T. L. Sturges, Jr., A. J. Wurts. (17.)

Elected by letter ballot, December 31, 1910: F. A. Berger, F. C. Bolton, A. C. Callen, G. W. Lamke, Chas. McGonigle, B. L. Miller, Everett Norss, C. W. Nichols, M. R. Richardson, W. J. Risley, L. K. Russell, E. O. Sweetser. (12.)

Elected by letter ballot, February 25, 1911: H. Berents, A. R. Crathorne, W. W. Crosby, F. W. Durkee, J. B. Frear, F. J. Kircher, J. J. Long, F. M. Mann, W. K. Monroe, E. B. Paine, C. W. Parks, J. A. Randall, Alfred Raymond, W. J. Raymond, H. L. Reitz, W. I. Slichter, H. C. Van Buskirk. (17.)

Elected by letter ballot, April 13, 1911: A. W. Berresford, J. C. Bland, L. F. Blume, C. C. Chesney, C. A. Coffin, C. W. Converse, E. L. Coster, Gano Dunn, A. J. Frith, L. H. Fry, Henry Gardner, F. A. Geier, W. P. Gerhard, J. F. Gilchrist, C. R. Grimm, C. T. Hagerty, W. J. Harahan, Henry Hess, T. S. Hewerdine, C. W. Hunt, E. P. Hyde, B. F. Lovelace, G. W. McCoard, C. T. Main, W. D. Marks, S. A. Moss, J. E. Muhlfeld, Willard Pope, E. L. Powers, A. B. Smith, F. H. Stillman, C. L. von Ende, G. A. Wells, Jas. G. White. (34.)

Elected by letter ballot, May 17, 1911: E. H. Beckstrand, R. H. Bradford, W. A. Bratton, Andrew Carnegie, H. H. Carroll, S. B. Charters, Jr., Paul Cloke, Chas. Day, J. A. Dent, P. M. Dysart, E. S. Foster, J. L. Gibson, Rudolph Hering, T. P. Holt, L. L. Hubbard, G. H. Hunt, G. A. Kelsall, R. B. Ketchum, A. A. Knowlton, F. W. Lane, P. M. Lincoln, F. M. McGaw, G. E. Molleson, Dalton Moomaw, Chace Newman, A. M. Ockerblad, L. A. Osborne, F. J. Pack, B. K. Philp, O. B. Poore, A. S. Rosing, W. T. Ryan, A. R. Sage, J. E. Shaw, H. G. Stott, H. R. Thayer, Chas. H. Tower, Wm. S. Turner, David Van Alstyne, J. M. Weed, Edw. Weston. (41.)*

ADVERTISING BY MONTHS.

Month.	Amount.
September	$ 95.00
October	102.00
November	97.00
December	85.00
January	82.00
February	97.00
March	97.00
April	102.00
May	97.00
June	142.00
Total	$996.00

* See p. 11 for list of members elected at the Pittsburgh meeting.

TREASURER'S REPORT, 1910–1911.

To the Society for the Promotion of Engineering Education:

The Treasurer would respectfully report the condition of the Society's finances as follows:

SUMMARY OF RECEIPTS.

June 18, 1910, Cash balance on hand	$ 342.20
July 1, 1910, to June 15, 1911,	
Received for dues, 1911–1912	17.00
Received for dues, 1910–1911	3065.48
Received for dues prior to 1910–1911	283.26
Received for Life Membership	200.00
Received from sale of Proceedings and Bulletin	346.08
Received from authors' reprints	69.72
Received from advertisements in Bulletin, Vol. I	886.90
Received stamps	.25
Received from sale of cuts	6.74
Received from interest on deposit at Lincoln Trust Co., July 1, 1910	12.27
Lincoln Trust Co., January 1, 1911	3.36
	$5,233.26

SUMMARY OF EXPENDITURES.

Postage and sundries for Professor Munroe	$ 14.77
Badges for Madison meeting	16.00
Reporting Madison meeting	81.00
Expenses of Treasurer for printing, postage, etc	117.13
Collection of out of town checks	7.89
Clerical assistance for Treasurer	75.00
Expenses of Secretary for postage, etc	193.03
Expenses of Secretary for printing, etc	317.63
Clerical assistance for Secretary	223.55
Secretary's arrearage on honorarium	150.00
Secretary's current honorarium	400.00
Secretary's allowance for editing and publishing Bulletin	350.00
The New Era Printing Company,	
For printing Bulletin, Vol. I	894.87
For postage, authors' reprints, expressage and sundry printing	361.69
On account for Vol. 18 of the Proceedings	750.00
Professor A. L. Williston for arrearage in honorarium	150.00
Professor A. L. Williston for commission on sale of Proceedings.	125.24
Cash on hand, June 15, 1911	1,005.46
	$5,233.26

ASSETS.

Cash on hand, June 15, 1911	$1,005.46
Dues from members and non-members,	
Dues	701.50
Advertisers	184.00
Proceedings, Bulletins and Reprints	191.11
3,147 Vols. of Proceedings on hand, valued at $1.00 each	3,147.00
	$5,229.07

LIABILITIES.

The New Era Printing Co., bill of March 18, 1911, for printing Vol. I, No. 9, of Bulletin	$ 116.70
Balance due on New Era Printing Company's bill of April 29, 1911, for printing Vol. 18 of the Proceedings	356.33
	473.03
Net assets	$4,756.04

The total amount due the Society is $1,076.61 as compared with $669.62 last year. There are 76 members one year in arrears; 29, two years; 12, three years; and 9, four years. The total arrearage in membership-years is $(76 \times 1) + (29 \times 2) + (12 \times 3) + (9 \times 4) = 206$. The corresponding number last year was 166.

Respectfully submitted,

WILLIAM O. WILEY, *Treasurer.*

ADDRESS OF WELCOME.

ON BEHALF OF THE CARNEGIE TECHNICAL SCHOOLS.

BY ARTHUR A. HAMERSCHLAG,

Director of the Schools.

Gentlemen of the Convention: On behalf of the citizens of Pittsburgh I welcome you to the city. On behalf of the faculty and trustees of the Carnegie Technical Schools, I extend to you the courtesies of this institution.

The proceedings of this Society at its convention are of real interest to the city, to our educational institutions, and to the many individuals who are interested in engineering education.

Pittsburgh must always be vitally concerned with the production of trained engineers, since it is prolific in setting forth engineering problems of magnitude which demand the trained engineer for solution. It may, I think, be said that Pittsburgh outranks all other cities of the country in the extent of the engineering problems which it is compelled to present to the engineering teacher and the educated engineer. We, of course, are particularly interested in the development of this institution of learning which is glad to be your host on this occasion, because it is one of the new experiments in education, an experiment of some magnitude; but so recently begun that your criticism and advice during your stay within our walls will prove of inestimable value.

We welcome suggestions from you as you go over our work because we know that out of your experience you may be able to guide us in channels which we have overlooked, and these suggestions will therefore be doubly welcomed and appreciated by our Faculty.

President Talbot, I am particularly anxious to explain to you how eager the faculty of the Carnegie Technical Schools, as represented by the School of Applied Science which has charge of the engineering branches, is to co-operate with your Society, and how they are prepared to utilize the results of the deliberations of this convention.

We extend to you a hearty welcome, and hope that anything we can do to make this occasion memorable, aside from what may be considered purely conventional business, will be laid on our shoulders as an institution.

RESPONSE.

ON BEHALF OF THE SOCIETY.

BY ARTHUR N. TALBOT,

President of the Society.

Director Hamerschlag, on behalf of the Society I wish to thank you for this hearty greeting. We knew that we should be well received here, but we are more certain of it now than ever. The Society will find, I think, that Pittsburgh is a very interesting place for a meeting. Its industries are so varied, its interests so diverse, that every branch of engineering science will have something of interest to members who are here. And I am sure that the members of the Society will be especially pleased to see the work of this new institution which has been established to take up the problems connected with Pittsburgh's individual conditions, conditions which belong to a large industrial city. Again on behalf of the Society I thank you for this welcome.

THE ENGINEERING TEACHER AND HIS PREPARATION.

PRESIDENTIAL ADDRESS.

BY ARTHUR N. TALBOT,

Professor of Municipal and Sanitary Engineering, University of Illinois.

THE past year has been noteworthy in the history of the Society in two ways: first, in the wonderful increase in membership, 1,070 members being reported by the Secretary, the teachers of the membership representing more than 133 colleges and universities; and second, in the establishment of the Society's BULLETIN as a monthly means of communication. Various influences are responsible for these advances, but the chief among them is the activity, energy, and loyal effectiveness of the Secretary. The President here expresses his appreciation of the Secretary's most valuable services; and he congratulates the Society upon having so efficient an officer. He wishes also to felicitate the Society on its prosperity and its growing opportunities for service.

Of those who attended the section of Engineering Education of the World's Engineering Congress in Chicago in 1893, sixty-three joined in forming this society. The large membership just reported and the large number of institutions represented therein show in some measure the great expansion of engineering education in recent years. Not only in instructional staff, but in numbers of students, in buildings and laboratory equipment, in opportunities afforded, has there been expansion beyond any prediction of 1893.

In view of this great development, made with more than normal rapidity, may it not be worth while to inquire somewhat into the qualifications expected in the engineering teacher, to ask what the methods of preparation for his high responsibilities should be, and to find whether conditions indicate that the future will see new methods of preparation and additional requirements?

It is axiomatic that a teacher should be a man of character, ability, and education. It goes without saying that he should be well versed in the subjects he teaches. Not only must he be able to impart knowledge, but he must know the principles of education, appreciate the aim of teaching, and use the methods which are necessary to attain results. Engineering experience and professional attainments also are generally considered essential. General culture, tactfulness, force, energy, balance and the various elements which go to make up a well-rounded man are usually thought of in counting up qualifications. How, then may the desired qualifications best be secured? How may the preparation and development best be attained? How may the selection of men and their advancement be made most effectively and satisfactorily? To what extent does natural aptitude overcome necessity for special preparation? Is the teacher born and not made, and to what extent has he like Topsy "just growed"? These are some of the questions which arise when a discussion of the qualifications and preparations of the engineering teacher is made.

It will be seen that the qualifications for the engineering teacher are even more severe than those expected in the general teacher. In addition to character and general education and scholarly attainments and knowledge of man and human nature and of pedagogical methods and principles, he is expected to have a broad training in engineering science, to have some considerable knowledge of engineering art, and to have had experience in the professional and business side of his work.

It will be admitted that the great teachers have had the power to impart knowledge and to impress their personality on their pupils, and that natural gifts may enter largely into the success of the teacher. But further than this we can not well go. Mere teaching aptitude is insufficient—the "born" teacher may not be a well-rounded and efficient teacher. I well remember doing service on railway location in mountainous country under a "born" locating engineer who could almost by intuition place the line in its predestined place. He could direct the party to back up so far, run in 245 feet of 15° curve to the right, and then blank feet of tangent. True, the line generally fell where he planned it should go, and the cuts and fills were as he expected them to be, but as I look back upon it now I conclude that I was right in thinking that he overlooked some of the fundamental principles of railroad location as known at that day and that the railroad company would have profited by having the location made by a man better versed in the science and economics of engineering and of railroading. Since that time the science and the art of engineering have had a wonderful development, and the methods and standards have changed until the "born" engineer has become a rarity. And I am not sure but if we looked into the history of the "born teachers" we should find a period of preparation, a time of growth, of opportunities for training, which would go far to explain the success of their teaching.

In discussing preparation for engineering teaching, mention may be made of undergraduate and graduate study, experience in engineering work and in business, pedagogical training and instruction, experience in the work of assistant or instructor, general cultural education and development, research work, etc. Granted that a man has had a strong undergraduate course and has shown marked ability as a student, what should his further preparation be?

A qualification in an instructor, commonly considered desirable by administrators of engineering schools, and looked upon somewhat askance by those connected with other departments, is that he shall have had experience in engineering work, and this whether the work directly applies to his subject or not. The qualifications set out for a teacher imply growth, maturity, breadth of view, knowledge of conduct of engineering work and of the world of affairs, as well as technical knowledge of engineering science. The old-time teacher has been characterized as narrow, unpractical, unbusiness-like, inexperienced in affairs, unable to take the point of view of

Library
N. C. State College

the business world—and possibly in some lines of education this charge was sometimes not without foundation. It seems certain that even a short experience in engineering work will be of considerable advantage in more ways than one to a young man beginning his teaching career. It will give him confidence. It will help to give him standing. His judgment of essentials and non-essentials will be better. Distance from undergraduate days will have improved his perspective in many ways. Some facility in turning off routine work will have been attained. His knowledge of life will have been added to. Doubtless in many cases this additional experience will be worth more than time spent in advanced study. And as a prerequisite to teaching certain technical subjects it seems quite essential that the instructor shall have had adequate professional experience in design and construction of engineering works of similar character. The professional training thereby attained and the acquaintance with men and methods, will also add greatly to the teacher's equipment.

But what of advanced study, of graduate work, of investigational effort? To what extent is this essential? To have taken graduate work has long been considered a recommendation for the engineering teacher. Have we come to the stage of development in engineering schools when graduate work shall be included among the essential qualifications? What should this graduate work be, and how much should be required? In some universities requirements are in force in the departments of science and in other lines that a man must have the degree of Ph.D. before he may be appointed even to the rank of instructor. Surely we shall not reach this point in engineering schools in many years, but the practise referred to shows the emphasis now placed on graduate work as a preparation for the teacher in other lines. However far we may equate engineering experience for graduate work in making up our estimate of the qualifications for the engineering teacher, we must not overlook the advantages which come from graduate work. Aside from the general development given by study, graduate work if properly carried on not only broadens the view and extends the range of knowledge, but it deepens the hold on basic engineering science. It gives an insight into the foundational parts of the subject. It develops independence and fosters originality. It takes the student away from dogmatic or conventional acceptance of views possible in undergraduate days. His analysis takes new life and his study of the work of the master investigators correlates laboratory work and analytical research in such a way as to give meaning to engineering science and its foundations. The knowledge which comes with this work is subsidiary in importance. To the man who plans to make teaching a life work, two or three years of systematic graduate study in engineering science and related lines will give a foundation which will enable the teacher in succeeding years more rapidly and more effectively to develop his powers and increase his opportunities for service. To the man who leaves teaching to go into engineering practice the development and training found in the graduate work is not less valuable. Whether the graduate study brings a degree is of minor importance; the need for thoroughness and system is plain, and the degree from an institution of standing is an evidence of accomplishment.

The number of students taking graduate courses in engineering science has been increasing in recent years. There is a growing recognition of the value of graduate work as preparation for the work of teaching. To my mind a great service may be done by the larger and better equipped engineering schools by outlining and giving courses of graduate work arranged especially for the prospective teacher and in promoting and emphasizing advanced courses for engineering teachers. Some institutions may be well fitted to give such work in certain branches of engineering science, while the strength of others will lie in other directions. In outlining graduate work, the needs of the teacher should be considered. Courses in pedagogy or in the principles of education and psychology will be found to be of great value. So many courses in nontechnical subjects will suggest themselves that it will be difficult to restrict selection to their proper proportion. So attractive is the field of graduate work and so full of advantage to the teacher that this phase of engineering education must be expected to have a large development in the future.

It must not be inferred from what has been said that the training of the teacher includes only that which may be obtained from study and from experience on engineering work. Teaching is an art, and the experienced teacher has learned the art through years of work, acquiring it in a variety of ways. Just what form of apprenticeship may be best for the young teacher will depend upon the circumstances. An assistantship during the period of graduate study or a term of service as an instructor under the immediate supervision of a skilled teacher should be very helpful. In our larger engineering schools frequent meetings are held in which the instructional force, by departments or groups, discuss the subject matter taught, the methods of teaching, the makeup and quality of students, and the general direction and supervision given in various ways are all very helpful to young and old alike. The discussions of methods and standards and educational principles with other teachers, the contact with student and with faculty give opportunities for growth. Participation in administrative affairs and contact with the business side of the work, which exist in a well organized school, will help in developing another side. The wideawake teacher will take advantage of his many opportunities in developing himself in the art of teaching, and the degree of his success as a teacher should be recognized and will be measured by student and school alike.

But the question arises, is care exercised in selecting engineering teachers and in retaining and promoting them? Are men set at important teaching tasks without experience and without knowledge of their problem? Is there insufficient or ineffective direction or supervision of teaching work? An address given before the students of an engineering school by a prominent engineer who for years held a position as head of a department in a leading engineering school, recently published in an engineering journal, contains a severe arraignment of teachers and teaching in engineering schools. Humbuggery, inefficiency, unbusiness-like methods. lack of supervision and direction, poor choice of men, degeneration with years, neglect of work—these are some of the charges and some of the terms used in the address. Now these are serious charges. They warrant attention. They can not be answered with denial or mere sarcasm. It is not the time or place here to review them or discuss them, or to pass upon their importance, but it may not be out of place to venture the personal opinion, formed from an acquaintance with Mr. W. D. Taylor and with a knowledge of his ability and candor and character and high-mindedness, that it was his purpose, in couching the statements in such terms, to ensure bringing prominently before engineering teachers and college administrators certain weaknesses in college administration which he believes call for remedy. Surely he did not mean in his exaggeration to make an indictment of the great engineering school with which he was long connected or to charge that the conditions of engineering education generally are as faulty as his phraseology would imply. His address may well serve as a text for discussion among college administrators and teachers. The maintenance of quality and efficiency is as important in teachers and teaching as in business organizations, though it must not be overlooked that the standards and methods are in many respects not comparable. The difficulties of finding the right men for positions and of learning the fitness of applicants is appreciated by those in administrative positions. Better ways of finding men and of determining fitness may yet be found, for the problem is of the highest importance.

The position of the engineering teacher differs from that of most teachers, not only because an experience in engineering work is considered a desirable element in his preparation, but in that the practice of the profession in some form and amount in connection with his teaching is thought by many to be advantageous to professor, student, and school. The thought is that connection with professional engineering work gives valuable technical information, keeps the teacher in touch with his subject, vitalizes his work, interests the student, and advances the standing of professor and school. Doubtless in many specialized subjects an arrangement may well be made by which a practicing engineer of standing may give part of his time to teaching a professional subject. Doubtless many a teacher has profited greatly through carrying on an engineering practice along with his teaching. Doubtless, too, public interests may be served through coöperation with engineering teachers. Evidently also teaching may be enlivened through references to actual engineering operations. But may not participation in engineering work be carried on in such a way as to detract from the results which may properly be expected from the teacher? If a man, for any length of time, does full teaching work, and gives as much or more time and energy to outside professional work, which work suffers? If a prominent engineering teacher, head of a department in a great university to which students are drawn by virtue of his reputation and prestige, and who is advertised to give and direct instructional work, devotes three-fourths of his time and nine-tenths of his energy to engineering practice, is it to be expected that the students of this institution will profit much by his connection with it or that the department will show vigor and energy? And when the participation in engineering work degenerates into mere necessity for filling out a meager salary, or even for extending the annual savings, without reference to the value of the work in the development or advancement of his usefulness as a teacher, the practice is indefensible. Surely there is great chance for the abuse of opportunity. Surely there is need for caution. In the first place every educational institution should be put on such a basis that the instructor will not need to depend upon outside work to meet the year's necessary expenditures. Omitting the case of specialized instruction and of special provision for part time engagement, and agreeing to the advantage of keeping in touch with the professional activities in his specialty, may we not with prudence say that the limit of outside work should be placed below any amount which will interfere with efficient instruction, adequate attention to the needs of students, and the requisite energy and zeal and ambition for the teacher's work, and that in its nature the work should be limited to that which will extend the experience and training of the teacher, or make an addition to professional knowledge, or be of special service to the community or the public in some way not possible by the outside engineer. And especial care should be taken that administrative duties and the direction or supervision of instruction be not interfered with by outside interests. Beyond these limits, participation in engineering activities may well be relegated to vacation periods and leaves of absence. When these limits are transgressed, it may be questioned whether the advantages of great names and high authorities compensate for loss of efficiency and vigor in instruction and of activity in the organization. The conditions of special cases where teachers are successfully carrying on important engineering operations without interfering with the conduct of their teaching, are so apparent as not to modify the applicability of these principles to general cases. It is worth while, too, to consider other methods of inspection and study of engineering work, opportunities which with the courtesies always afforded the teacher may in the same space of time give several times the knowledge and general development to be obtained by connection with a single piece of work.

The engineering teacher may be expected to have developed qualities and experience which will be serviceable in the practice of engineering should necessity or choice take him into practical work, and his teaching experience will be found valuable. But what of the practicing engineer, trained and skilled on the practical side of the work? Will he make a successful teacher, is a question which is often asked. He has the development gained from a business experience; he has met the problems of administration; he has matured in mind and in judgment, he has grown in technical knowledge; he has become learned in human nature. To what extent do these offset his remoteness from the student stage of development, his habits in routine work, and his respect for detail and completeness. Numerous examples are at hand where practicing engineers have become successful teachers, but it may be expected that unless they are caught young there is more than ordinary risk in the trial. Possibly two exceptions may be named—the instructor in highly specialized professional subjects, and the man of administrative experience who takes up duties which are largely administrative.

In this discussion, the teaching function of the engineering school has been in mind, and the well-being of the student has been the prime consideration. The two other functions of higher institutions of learning, research and public usefulness, are not within the scope of this address, although it may not be out of place to refer to the indebtedness of the engineering profession to engineering schools and engineering professors for their important contributions to engineering science and to express the belief that in coming years the contributions in investigation and research will be larger and more important.

The topic of this address may seem trite to you—the opinions advanced may not be agreed to—but the theme is a live one, and the advancement of engineering education depends upon the quality and efficiency of those to whom this great work is entrusted. Teaching is a high and honorable calling. The inspiring teacher helps to mould the youth and affects his life in ways that are far-reaching. The indirect effect on the world's activities and standards are no less marked. With the continued development of the vast resources of our country engineering activities and operations have come to take a leading place. Engineering education is called upon for greater efforts. There is need for more efficient work, for better comprehension of the problems, for higher standards of work. Great as have been the accomplishments of the past, improvement should be the watchword of the future. Shall we not work together to raise the standards of the teaching profession higher and ever higher? And may we not expect the Society for the Promotion of Engineering Education to be a potent agency in advancing the art of teaching and in establishing standards of accomplishment toward which the engineering teacher of the future may well strive?

ENGLISH IN THE ENGINEERING SCHOOL AT TUFTS COLLEGE.

BY SAMUEL C. EARLE,
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The papers of Professors Telleen and Kent and of Deans Anthony and Clark, read at the last three annual meetings of the Society for the Promotion of Engineering Education, are evidence not only that engineers recognize the importance of ability to use one's native language effectively, but that they are giving more and more thought to methods of instruction in English. For this reason a few somewhat radical experiments which the English department at Tufts College has tried will, I believe, prove of interest to the members of the Society.

We have departed from common practice mainly in three ways; in shaping the work in English more frankly and more completely for engineers; in giving systematic training in technical writing; and in adopting special means of increasing the efficiency of the work. I shall attempt to suggest something of what we are doing under each of these heads.

I. English for Engineers.

The attitude toward the subject of English is different in different engineering schools. In some colleges the students in engineering are sent to the academic department for all their instruction in English; in others they have their separate English teachers, yet are given purely academic training. Even in those cases where the work is specially adapted to the engineering course, there are wide differences in the interpretation of what should be sought by such adaptation. Some instructors consider that it is enough if they condescend to the limitations and in part to the special interests of engineers in order that they may bring this work in English as nearly as possible into line with traditional college teaching. To them any radical change in method or purpose is repugnant because they consider English as the last bit of salvage from the arts course remaining in the engineering school and as the only means of true culture in a curriculum otherwise hopelessly practical. Other instructors would limit the work to what might be called a course in business English, on the ground that engineers have neither time nor need for broader training. At Tufts, the Engineering School is regarded "as an institution for educational development, and not solely as a training school for one or more classes of professional men. Our aim is to provide the best education for that class of young men who may better secure their collegiate training through channels which carry a greater degree of technical work than do the schools of letters."* Of this educational development, English forms an organic part; like the other subjects in our course it aims to give broad, collegiate training; and, like them also, it strives to attain its object through the technical training of engineers.

Our freshman English begins with a lecture on the engineer of the twentieth century, and according to the demands of that ideal we shape all our requirements. This is not a preliminary promise to catch the interest of the students; we are frankly committed to the principles that we should set no task which we are not prepared to justify even to those who "want only engineering subjects," and that the attitude we ourselves should always maintain toward the work is that of the engineer. This does not free the subject from limitations. The students of engineering generally have not had previously and will not have in the course so much work in language or in literature as candidates in arts; their ability in such subjects may be less; and their interests turn in other directions. Yet a careful consideration of the needs of the profession leads to an elementary course as thorough, as broad, and as varied as that given students in arts; and, when the subjects are

* From the Report of the Dean for the Year 1909–10.

properly presented, engineers are apt to put into their work more original and earnest thought. Moreover we find, as I believe everyone will who studies the case without prejudice, that for those who have already entered upon what is to be their life work, true culture comes not from turning aside to other interests as higher, but from so conceiving their special work that it will be worthy of a life's devotion.

The more advanced (elective) subjects in composition are also shaped especially for engineers, the best illustration of which is the subject of argumentation. In colleges this subject has dealt mainly with formal forensics and debates. The training which this gives is valuable for anyone, but we do not offer it because the engineer will probably find no occasion to argue in such formal ways. He will have opportunity, in his engineering societies, to enter into discussions or even informal debates; and for that kind of speaking we try to give practical training. On many occasions where there is no discussion, the engineer needs to be able to present subjects convincingly; and we pay even more attention to preparing our students for handling technical subjects so as to win a favorable judgment. Above all, the engineer needs to be able to carry on investigations not so much in order to convince others as to form a just opinion himself; and to that end we shape the main part of the work. In turning from the study of formal forensic writing to more practical argumentation and in putting the main emphasis on the formation and expression of just and unprejudiced opinion, we are adapting the subject to the needs of the engineer, but instead of lessening the value of the training, we believe we are doing exactly what should be done in any undergraduate course.

The contract under which we work at Tufts requires us to train engineers, but not simply engineers who are hired men. The graduate should be able to work with others and over others. He needs to know something of life and its problems; consequently he is required to study economics, and for the same reason he will profit by the study of the literature of the past. But even the various subjects in literature must be shaped entirely for engineers, if we undertake to live strictly up to our principles. Not that we attempt to treat the subjects in a ''popular'' way; too often that means the degeneration of instruction into entertainment. We simply bring each subject as a whole and in all its details into real relations with the work of the engineer. This might seem to put a deadening limitation on the instructor. On the contrary, we have found that it is a strong incentive to the best work, for it means that the teacher must come out of the closet of his own special research and so present the subject that it becomes attractive and of definite value to young men of different and seemingly opposing interests. Many of the technicalities with which the special students of literature are concerned must be left out, it is true, for the engineer simply needs to learn how to use a library as a means of mastering new subjects and to gain a clear idea of the value and the interest which the past has stored up for him. But of the important matters of history and literature, few if any are without value to the engineer, for the only rational ground we have for calling them important is that they have been instrumental in bringing about present conditions and so shed light on live problems of the present. Here again we are shaping the work for engineers, but we believe that to humanize the subject is an advantage to any general student.

II. Training in Technical Writing.

Everyone who has any real knowledge of engineering literature knows that it is a form which it is difficult to write effectively. ''Contrary to the popular notion, the creation of so-called 'atmospheric' impression in literature is much easier, and of a lower order of intellect, than to convey in familiar words exactly what was done and why. This also takes imagination.''* And when the task is not one of recording merely, but of constructive creation, as in writing a long technical report, magazine article, or book, great skill is required to give really adequate treatment. Yet it has been commonly assumed that for such writing a course in general composition is enough. No lawyer, minister, dramatist, novelist, or poet would assume that because he had had general training in composition he could become a master of his peculiar form without special study. Certainly the engineer, using a form of discourse which, unlike the others, has not been carefully studied, and reading technical literature much of which is by no means effectively written, has no less need for special instruction. Clearly the engineering schools should give him the instruction and the practice he needs, not merely in literary exposition (from which he will get little help in his special difficulties), but in writing on technical subjects.

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* Charles D. Stewart, in the *Atlantic Monthly* for October, 1908.

Many seem to think that if a piece of technical writing is not satisfactorily done, all it needs is to have a few commas added, a sentence tinkered here and there, and certain words replaced by more elegant expressions. This is seldom enough. If the defects are at all serious they go to the very foundations. The subject needs from the start to be thought out accurately and completely, and to be expressed in such logical form that the special readers addressed will get just what they need to know with no waste of effort because of shortcomings of the writer. For these reasons we give an elementary course in the principles of technical exposition in which a few typical subjects are studied minutely in order to make clear the chief fundamental problems of engineering writing and to give the students a thorough logical drill. In addition to this we give an advanced course in the writing of theses on research or construction work which the individual students have done.

This special drill in technical writing is not intended to take the place of other work in English; rather it is additional —the final bringing of the training in composition into relation with the special problems of the profession. The extra time required would lead some to prefer to leave the student to work out his problems blindly by himself; but the work may be justified as valuable general training. In the old-fashioned college course, the years of training in exact expression required by the study of Latin gave the students thorough drill in exact thinking. The engineer seldom has the advantage of such discipline, and the natural results show in the loose thought and still looser expression of the majority of technical graduates. For the needed mental discipline a course in technical writing offers one of the best opportunities.

Many believe that it is the business of the English instructor simply to teach the use of correct English, not to give mental discipline which will help the student to think. There is discipline enough, they say, in the technical subjects in engineering. But work in applied science is defective as general discipline at the very points where a course in technical writing has its best opportunities. Let me explain briefly four of the most important of these opportunities.

In the first place, much of the thinking in applied science is done by means of visual images and symbols, and not in words. But thought and language are so nearly inseparable that, at least in the case of the ordinary undergraduate, when the thought has not been carried to actual expression in words there is always ground for questioning the accuracy or the completeness of the thought. In most cases when we hear it said, "I know but I cannot express myself," we find, if we make investigation, that the student does not quite know. And we generally find that, if he is led to attempt to put his ideas into exact language, he will either arrive at full knowledge or will at least get an exact idea of what it is he does not know, which is the first and most important step.

In the second place, a large part of the thinking done in the science courses is carried on with the objects themselves at hand and generally in actual use. But in some of the most important parts of engineering work, such as designing, inventing, planning, and organizing, the thinking has to be carried on with the objects present only as ideas. And reasoning without the objects present to suggest, guide, and correct thought is much the more difficult. We frequently get students who insist, for example, after having used transits for a year or two, and used them satisfactorily, that the verniers are on the same plate as the graduated circle. So much more thorough mastery comes through working out a complete explanation of an instrument or of a process without the objects present—as is required in the English class—that we find most of the students ready to spend the time required to write up the subject, as soon as they have grasped the method, for the sake of what they learn about the instrument or the process.

In the third place, the English class gives an opportunity to train students in expressing themselves effectively to different sorts of minds. In their other subjects, whatever they undertake to explain is addressed to the instructor, that is to say, to one who knows more than they about the subject and who, in all probability, is mainly interested in discovering a hint here or there which will enable him to determine how much the student has got from the special instruction given him. Writing of this sort is quite different from explanation which is in itself clear and complete; and passing back ideas to the one from whom they were received is much simpler than explaining one's self to different grades of knowledge and of interest. Much of the writing done in the subjects in applied science is of a nature to incapacitate the student for explaining his ideas as he should in an engineering report, to say nothing of making a technical subject clear to a non-technical reader.

In the last place, the English class gives opportunity to train men in thinking and expressing themselves completely and accurately. For this, at least, it might well seem there should be no need, for is it not the essential purpose of all the work in the engineering school to train students to think? But in science courses subjects are not treated completely; many are taken up part here and part there in various connections. It is the business of science to proceed step by step along an endless path. Literature on the other hand, being an art, insists on bringing things into unity. Now a certain amount of rounding up ideas into relatively complete wholes is most valuable in gathering together loose ends, in bringing out relationships, and in fixing facts in the memory. As for accuracy, if the science instructors always insist on results, that is about as much as can be expected. Attention can seldom be given to the way in which the student thinks out his results. With large classes and the consequent small amount of attention given the individual student, and with the increasing amount of work to be done and the consequent haste, it often happens, in spite of all the instructors can do, that students in the elementary subjects are not only permitted to continue slack habits of thinking but are actually led to develop such habits, so that much effort is required later to unlearn these lessons. In the English class we take up a few subjects, not more than a half dozen a term, and study them so minutely as to give the students a realization of what accurate and complete treatment means.

Naturally the good results obtainable in such a course in technical writing would not be possible if the students were not at work at the same time in their science courses; but the English class gives opportunities to knit together many loose ends of training and to make special study of the possibilities of effective thought and expression in dealing with technical subjects. It lays the foundation for more efficient work in all the remainder of the engineering course and after graduation, such a foundation as every student in college should have, but which each should get by writing on those subjects of which he has special knowledge.

III. Efficiency.

Much has been done during the past generation to make the teaching of English more efficient. It is now generally recognized that the object is to teach students to think and to express their own ideas effectively, rather than to require them to explain or to apply principles of rhetoric. The work has become more and more personal, that is to say, a study of the difficulties and the possibilities of the individual student in conference, rather than theoretical class instruction. In the last place, the college methods of the recent past, which tended more and more to unfit a man for using spoken language, have been so changed that students are being taught to speak as well as to write. Not all schools have yet adopted these methods, but they are in general use, and if we have tried to accomplish all we could at Tufts by these means, we can claim nothing original. We have, however, sought efficiency in certain other ways which are not generally recognized. I shall speak of these under three heads: efficiency in the work of the student, efficiency in the work of the English instructors; and efficiency of the school through coöperation.

The efficiency of the ordinary student in English is under all circumstances difficult to maintain. He can already read, speak, and write his native language in a way that serves; and, no matter how hard he strives to improve, progress seems slow and uncertain. For years he has labored over English till he is tired of it, and the subjects he is generally asked to write on are not in themselves interesting enough to carry him through the wearisome process of composition. The secondary schools more frequently discourage the student over their shortcomings than instill into them interest and ambition. The instructor can do much through sympathy and personal knowledge of the students; but in addition he needs to consider two facts. In the first place, no one can write to advantage on a subject about which he knows little, and the untrained certainly cannot do themselves justice on subjects in which they are not interested. In the second place, the knowledge that the writing is to serve no real purpose is enough to wilt the nascent determination of any but those who have natural talent for writing. In spite of these facts, teachers ask students to write mainly on subjects about which they can have no real knowledge and in which they are not at all interested, and frankly consign the papers to the waste-basket after they have been graded. Obviously if we would increase the efficiency of the work we must cease to require students to do what we should revolt at doing ourselves.

Great care needs to be exercised in choosing subjects about which the students have some real knowledge; and by giving thought to the matter many may be found which have real use. The mathematics department, for example, wants a concise explanation of the process of interpolation to be used in class instruction; or the drawing department would like to have the students carefully write up the method of plotting a curve. The college newspaper wishes news reports of all sorts and thoughtful suggestions on any subject of college interest. Many good suggestions as to class methods, fraternity life, the athletic situation, and similar subjects will come from the undergraduates, and if the instructor talks each suggestion over with its author and explains other views of the subject, he often can interest the student to write a strong defense of a good proposition. We have often sent to the Dean, to the President, or to the Trustees a freshman suggestion which has helped to effect an important reform. Then, too, the college literary paper is always on the lookout for good stories and critical articles. It is surprising how much interest freshmen engineers will take in writing stories, and how much they will gain from such writing. Some forms of writing which we wish to require we cannot put to such immediate use; but we can often make the subject interesting to the student. At the time we call for a character sketch, we invite an engineer who has had much experience in handling and in estimating men, for example, a manager of a branch of a great electric company, to speak to the class on character in engineering and how to judge men. When we wish a reminiscence written, we call in, let us say, a member of the faculty who has made some notable explorations, and have him tell stories of his work. As a result most of the students no longer write simply "themes." In spite of all we can do, there is some writing without interest or purpose, but we watch for it and in conference we can in part overcome the difficulty, so that we may hope in all cases to make writing wait upon knowledge, interest, and recognition of real purpose.

The efficiency of the instructors is much more easily developed; and it is surprising that so little is done in many colleges and schools to fit the teachers for the work they are to perform. Attention enough may be paid to seeing that they "know their subject," but except in advanced work that is by no means all of the real need. At Tufts we require each new instructor in English to serve a year's apprenticeship. During that time he has papers to read and conferences to hold, but no charge of classes. Moreover, he is required to attend all the classes in English as listener and critic. To many this would seem needless waste, but we have not found it so. The real waste is to let a man blunder into his teaching without exact knowledge of his predecessor's experience. The new instructors we engage are without experience as teachers, and by attending classes they not only have the needed opportunity to learn what past experience has taught as to methods, but are able to suggest many improvements. Since they are generally nearer the students in years, position, and interests, they can observe the actual working of the system, the real success and the many points of failure, much more accurately than the teacher in charge. Such apprenticeship requires the teacher to do much himself that is usually turned over to assistants, but the gain in insight and in suggestions more than pays.

We also require all our instructors to spend as much of their time as possible with the instructors of other departments that they may be in actual contact with engineering work, that they may know exactly what their students are doing in other classes, and that they may have the opportunity of looking on their own subject from other points of view. We allow them time and encourage them to study, to write themselves, and to assist fellow instructors and others who may be writing, in order that they may overcome the warping influence of dealing entirely with immature minds. In the last place we keep the whole department in contact with English as it is used in the engineering world beyond the college limits by calling in well-known and successful engineers to speak on various practical problems of writing. It is difficult to get speakers who are satisfactory, because many are unwilling to express their views on the use of English before a teacher of the subject, and because many are unable to grasp the freshman position; but all teachers need some such check on their work. One who studies the art of composition from the teacher's side of the desk only is certain to give undue prominence to his personal hobbies and is in constant danger of losing contact with real life. The practical man may come to have unworthy ideals in writing, but after all it is he that puts the training to real proof.

Our situation makes it possible to bring about helpful co-operation among the members of the faculty, which increases the efficiency of the school as a whole. The English conferences with the freshmen are held while the men are in the drafting rooms or in the shops, so that at least one English instructor is present while most of that work is carried on. This helps the students to think of English as a part of their technical training rather than as something which takes them away from engineering buildings. In addition it makes possible continual co-operation between departments. For instance, the English instructor, in talking over a character sketch in which the student has given simply the external appearance, is trying to lead the writer to see for himself other possibilities. The student does not catch the idea, when the instructor in drawing, who has overheard a part of the conference, asks, "How about the dotted lines?" and the student sees at once. Or, circumstances may be reversed. The teacher of drawing, in explaining something to his class, has occasion to pass from the consideration of graphic language to some point of verbal expression, and he immediately calls upon the English instructor for his opinion. Instructors in English in engineering schools should be trained engineers, and teachers of applied science certainly ought to be masters of good English, but the ideal is seldom fully realized. As a substitute, co-operation is a great help.

The general possibilities of coöperation between the English department and the other departments in the engineering school are numerous and very important. More than that, they are much more easily put into practical operation than those who have not made the attempt realize. I have already mentioned occasions on which the English instructor can get his class to write on subjects of value to other instructors; and there are many opportunities for such work during the four years. Then it is possible to bring into the English office much that is written for other classes, such as examination papers, reports, and theses; and conferences may be held with the students on these papers. To give students a few hours per week of artificial drill in the use of language in his "English" class, and neglect the real practice in speaking and in writing which they get all the rest of the time is certainly poor economy. We find it possible to have some influence over the language opportunities in everyone of the freshman classes and over enough of the sophomore classes to have a real check upon the students' work. In the upper classes the work we can do with the students is voluntary on their part, but with proper habits formed during the first two years a large number continue to look to the English department for help. In all co-operation with other departments it is of the first importance that the two instructors concerned work together over enough of the papers to bring them into understanding and agreement; otherwise there is almost certain to be serious friction. From his associate, the English instructor gets helpful insight into matters of an engineering nature and the opportunity to see his own work through the eyes of a mature person who is not a professional teacher of English. On the other hand, the instructor in the other subject not only keeps in contact with good practice in writing, but often gets help in presenting his own subject from working with one who is more mature than the students and yet may have even less knowledge of the special subject.

The position of English in the curriculum is different from that of any other subject, for the reason that no teacher in the institution can help exerting influence, good or bad, over the students' use of their native tongue. The training the student gets depends not on the teacher of English alone, but on the general attitude of the faculty toward the subject. This is specially true in a professional school. If any teacher in speaking or in writing shows himself ignorant or careless, if he cannot use standard English, if he cannot express himself without confusing those he is addressing, he is exerting harmful influence. Even an instructor who is careful himself, if he permits his students to use wretched English without protest or with the simple comment that he has no time to spend over poor English, is giving the suggestion that correctness of form and clearness of expression are of entirely secondary importance in practical work. Since this suggestion is naturally welcome to those students who are having difficulties in writing, it will in many cases be more powerful than anything the instructor in English can give in the few hours he may work with his class. On the other hand, if the instructor insists that accurate thought and clear expression are essential parts of all the student's work, he is teaching English whatever his department may be; in fact his influence is greater if he is not a professional teacher of English. Many teachers of science think they have no time to devote to form of expression, or they feel they have not the technical training necessary to deal with language questions; but the teaching of adequate expression within his special field is an essential part of every instructor's business, and whether he recognizes it or not no teacher can escape training his students in the use of language. It is not a question of thorough mastery of "good use," for many of the technicalities of the rhetorician are of little real importance; it is not a question of always being right—many good teachers of English are far from models themselves. The important thing is to realize that the writer should always express himself accurately, completely, and in such form that the reader gets his meaning without unnecessary effort, and that the writer should avoid such language as will distract the reader's attention from the subject matter and center it on the writer's ignorance or carelessness. By proper methods of co-operation we believe it is possible to make the whole school a unit in teaching good English.

Results.

At Tufts we have been working under specially favorable circumstances. Members of the Faculty have been ready to spend much time reading papers with us and assisting with suggestions, and above all, we have had the advice and criticism of a President and of a Dean who are not so much specialists in engineering as expert educators. Yet we have had difficulties to overcome. Many of our methods have been, as far as we know, innovations, consequently we have had to cut and try without the guidance of previous experience; we have had to discover and train our instructors; and we have even had to write all our text-books. The success of our methods we cannot judge, but we believe that where they have not worked well the failure has been due to defects in the human instrumentalities. It is our ideal to keep our work strictly training for engineers, to meet every practical need as fully as possible, to help in giving the students the broadest interpretation of the profession, and to take advantage of all the opportunities for training which the curriculum offers and of the conscious and unconscious assistance of all the instructors. We believe that the results of our work, both in composition and in literature, will compare favorably for thoroughness and breadth with those attained in any general collegiate course, and that we have but applied to ''English for students of engineering'' methods which would increase the efficiency of the teaching of English in any school.

THE PREPARATION OF WRITTEN PAPERS IN SCHOOLS OF ENGINEERING.

BY F. N. RAYMOND,

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Professor Earle has described the work of the "English" instructor and explained somewhat of the motives and conditions which govern that work as it is now conducted in some, at least, of the schools of engineering. In this paper, therefore, I shall omit much of what I had thought of saying about that, except to reënforce, if possible, some of his statements and to use some of them as a starting point for my own. Especially I wish to call attention to Dean Anthony's remark* that he believes the method of conducting the English work there described is the proper method, not only for the school of engineering, but for the other schools as well; the school of medicine, the school of law, the college of liberal arts.

I wish to present to the Society some considerations which may form a basis for the practical discussion of the whole matter of using written papers and books to best advantage in the engineering-school work. The statement is necessarily much condensed; I hope it will be suggestive. This society has often considered subjects which are really phases of this large one, and has shown that the efficiency of this kind of work is of interest, directly, to all departments of the educational system and to the men who have to use the services of our graduates. The discussion to be brought out will secure, it is hoped, some clearer understanding of the character of the training that is to be given and a greater degree of common effort, by all who have anything to do with it, to secure the best possible results.

Let me review some commonplaces. The writing of papers and the study of books are to be regarded, in themselves, as one kind of work. For want of a better name this is often called "English," and its formal study put into a special department. But it is used in all departments, both as a means of education in itself and as a vehicle in the use of other studies for the purposes of education.

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* This remark was made by Dean G. C. Anthony in connection with the abstract of Professor Earle's paper which he presented.

The best basis for organizing the study and practice of composition seems to be that of purpose. Methods which are too formal, in teaching, are dangerous, because the material to be worked in is the student's mind, and this is not to be shaped arbitrarily by pattern but developed in its own characteristics and its ability to work. At the same time some elements of uniformity have to be secured, because the very nature of scholarship is co-operative.

The great practical aim of a course of training, then, it may be said, is that the student be enabled to write independently next year; that is, that he be able to give other men information which will be useful to them and in such shape that they can use it.

The young man entering the field of scholarship has to learn what this service means. He has usually to learn the difference between committing to memory and reciting lessons of fact and precept which his teacher sets for him, and that kind of study which begins with gathering knowledge by his own observation and proceeding to reason upon it, with no answer in the book, but with the view to forming results which are the best humanly possible. This is education for service, indeed, but it is also the foundation for the development of genius (where genius exists), and the natural beginning of culture.

The practical difficulties a student encounters in approaching original studies are the unexpected complexity of real problems and his inability to use effectually what knowledge he has. He is in a new world intellectually, yet he has to learn to walk for himself. We can encourage him but we cannot, beyond a certain distance, teach him the way.

The immediate lessons, then, are those of accurate and thorough observation, clear perception of purpose, and adaptation to purpose. These are, of course, the essential elements of all study; they belong conspicuously to rhetoric because the verbal statement is the direct embodiment of the thought. Along with these must be developed the spirit and habit of good workmanship. The language, for most men, is mainly the instrument of mental work, a few hundred words and a few rules of grammar and conventional forms of statement. These form a code of symbols by which men represent their knowledge and opinions; they are fairly easy to learn, when one pays attention, but the real problem of using them lies not in the forms themselves, but in the knowledge and opinion underneath. But good results require good work.

The skill of language, however, from accurate spelling up, comes with the increase of knowledge and refinement of thinking and with the growing spirit of care in handiwork.

The actual manner of organizing classes is less important than are the recognition of its character and the co-operation of all departments to secure its effectiveness. The ideal method would be for each student to be so intimately associated with an all-wise teacher, no matter what the special subject of instruction, that his whole school work would be directed for his best intellectual development. This would involve a continuous preparation of reports and other papers of all kinds, and their best criticism. Somewhat of this is provided in particular schools and by particular teachers, but the great number of students and the extent of business in most schools make it impossible. The inconspicuous student in his years of general preparation, at least, goes through the mill and comes out as he may. The dean is overworked, the drawing and language and mathematics give place to special studies; see, then, what an opportunity is open to the writing work, which is the only element to run through consistently with natural development during the whole four years—from freshman rhetoric to senior thesis!

The system, then, we will say, is to be formulated along lines that will be quite definite and yet pliable enough to fit the service of all departments. It will have three main parts, the required work of the studies in ''English,'' that is, the writing of papers and the study of books in the formal way; the required use of written papers and books in the study of other subjects; and the similar work which may be undertaken by the student for various reasons with such assistance as he can secure. This course is printed in succinct statement and each student and each instructor understands that it is to govern all the work of this character (except, of course, as changed for special reason in particular instances) throughout the four years. It is accompanied by a code of the standard forms of words, symbols, manuscript, and other parts, as far as it may be desirable to make these formal. If for any reason modifications or changes are desirable for special departments they may be prescribed by that department.

The special work of the ''English'' department, I believe, for the best results, consists of the freshman rhetoric and some kind of advanced composition with what provision may be for other help when the student may ask. Skill in writing is not to be taught to a great extent but grows gradually along with the increase of knowledge and the refinement of judgment. Spelling, grammar, and the other conventional forms of language expression are not to be taught finally. Year after year of observation have shown that just ninety per cent of the students who came to us are weak in spelling and grammar, and in all cases that this weakness is grounded in poor eyesight and poor habits of workmanship. I do not believe in the ''natural-born poor speller who is good at other work.'' Not one of the men under observation has failed to improve as he learns to use his eyes accurately and to hold himself responsible for greater attention in all kinds of handiwork.

The rhetoric course is therefore mainly introductory, to put the student into the right attitude toward his new work, to make him acquainted in a general way with the language used by his craft, and to teach him somewhat of mental discipline.* It need not be a burdensome course, but should have weight enough to command its share of real attention among his many occupations; three hours per week for the year is probably enough.

The advanced course in a way follows the pattern of the former, but at a stage of the student's life when he has greater knowledge, more definite outlook, and more maturity of mind. It guides him as far as he is able to go into the meaning of men's work. It studies the nature of human knowledge, the means men have for acquiring knowledge, their natural methods of developing it and reasoning upon it and putting it to use. It points the way to the study of all subjects of human interest, even to the study of men.

Such a course need not be long nor require much time during progress, but it must be heavy enough to demand the most serious of mental effort. In our scheme it is given three hours per week for one half year.

Scientific reports and other technical discussions form admirable means of studying methods of study. They are obviously purposeful and of the same character as the knowledge they represent. Accuracy and methodical progress are necessary on the surface of them. They are interesting, too, for both writer and reader, and easy means of arousing the schoolboy from his lesson-reciting to original study. Even the slow men seldom fail to find a new interest in their work when, after a few preliminary exercises, they discover the meaning of a request for an accurate matter-of-fact statement of information. To make this incentive more forceful, and also to do a real service in the conduct of other work, it is well to have these reports designed for actual use—that is, for contribution to a manuscript library in the rooms of the rhetoric department. Such a library containing description of places, condition, plants, methods of engineering work, etc., has been found to be remarkably useful.

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* The practical work of the rhetoric class may be briefly indicated. The first exercise is always a statement of the student's name, place of residence both at home and at school, school experience, travel, and such other information as may be helpful to the instructor in laying out his work. This statement is obviously matter-of-fact and for real use. After being criticised and extended by oral discussion it is rewritten and becomes a permanent record. Next is assigned an explanation of the special work the student expects to do at school and a description of the equipment provided for this work; this statement is never satisfactory to the student, but it shows him somewhat of what is to be learned. Then he is asked for information about the town from which he has come to school; he offers first a gushing commentary, but upon questioning soon learns to give maps and specific facts, and discovers the gaps in his own previous knowledge of the most commonplace things. He is practiced upon sidewalks, broken fences, small pieces of machinery, with careful attention to dimensions, materials, etc.; and presently is sent to make descriptions, and later to make reasoned discussions which are needed in work which older students and instructors are doing. This practice, of course, lasts throughout the whole of a student's course at the school.

The written papers required by other departments vary from brief records and reports of work done to the elaborate senior thesis. At Kansas a so-called "technical report" has been required of each student in each semester when he has no other special writing to do. This practice has lately been reorganized and become very profitable. The task is assigned for each student early in the term by some instructor in engineering, preferably upon some subject that is offered by the student; the paper is specified as 2,500 words in length and with certain characteristics; it is submitted in January or March, criticised, revised, and after acceptance is deposited in the library of the school. Each student ordinarily during his four years, puts into the the library four papers of this kind and his graduation thesis. He is not apt to resist the temptation to take pride in them. Incidentally, the sewer systems and power plants of the various towns in the State are pretty generally on record in our school library. Such written work as this, by its continuance through the whole four years and in its evidence of the interest shown by the professional men, is for many students the real force of the system.

If these studies have accomplished their full purpose the student is inspired with the wish to continue the same kind of work. From what I have seen I do not believe in extending the formal rhetoric work beyond these two courses; I certainly have doubts of journalistic instruction for any but those peculiarly adapted to it. Studies in literature, history, economics, beyond those prescribed, are offered in the University, however; and the "English" department should be made the natural headquarters for those who have the liking to "spill ink" and to inquire into books. The "technical reports," which are to be judged by men in other fields of interest, furnish us a convenient means of laying out systematic studies and courses of library research. Men come to us for references and help in making bibliographies and card indices. They come to us to criticise their society and other public speeches, and their contributions to the newspapers. They come to us even to criticise their songs. The "English" department is not to be looked at as a sort of applier of varnish to hard-grained science, but as an editorial council for the promotion of whatever intellectual product may be offered. And the "English" department ought to be large enough in spirit and in numbers to fulfill this duty.

Two topics, then, I wish to present especially for your discussion, besides the general subject of the character of training that may be done by the English department. The first is the possibility of compiling a code of authoritative forms, so far as it may be desirable to have such forms, to govern the use of special terms, abbreviations, capitalization, forms of manuscript, tables, bibliographies, illustrations, etc.* The other is the organized co-operation throughout all departments to secure the best results in the matter of preparing written papers and work of similar nature.

Discussion.

Mr. Wm. Kent: One way we had of teaching English at Syracuse was to call upon each engineering student for an occasional report. He was expected to visit some works in the neighborhood of his home to examine its steam boiler-plant and to bring back a report: ''Such a report as you would make to a man who might consider buying the plant, but as he has not seen it, he sends you to inspect it. Tell all about the boilers, their size and make, and anything else you can learn about them. Ask questions of the fireman, engineer and anyone else who can help you. The idea is not to find out how to investigate a boiler plant, but whether you know how to report to a man who wants to buy a boiler plant so that he will understand just what it is like.'' We got in this way a report from every student, and this was turned over to the English department for criticism. One of the reports was mimeographed and handed to the class with the statement: ''Here is in one sense a model report. Every question has been asked that ought to be asked and the essentials are here. But at the same time it is the worst example of English in the lot. It is three times as long as it should be, and it contains bad spelling and composition. Your next exercise is to find out the facts in this report and express them in one-half the space.'' That was a good exercise. A year or two after that I got a letter from the writer of the report. He said, ''Please don't have this letter mimeographed, but that was a good lesson for me.''

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* Such a code, it may be said, has been undertaken, in a tentative way, since this paper was written.

Professor H. S. Jacoby: I would like to ask Mr. Kent what his notion is in regard to the relative value of these two kinds of work: first, writing the original report; and second, correcting the report made by the student himself or by some one else.

Mr. Kent: I think the correction of the report is worth about three times as much as the original writing of it. Originally the man writes down what comes into his head without any idea of composition. The man who criticizes the report has to use his critical faculty, and has to bring all of his knowledge of composition to bear upon it.

Professor J. M. Telleen: As a teacher of English I am naturally interested in this discussion. Professor Earle has emphasized the fact that English is a fundamental subject, based not only on the matter of good usage in the selection of words, but also on the application of the principles of logic. Accordingly it falls to the lot of the English department to teach the process of analysis and synthesis and then to indicate how the same is applied in mathematics, chemistry, physics, mechanics, etc. The courses in logic which are given in several of our engineering colleges must accordingly be considered fundamentally scientific. By breaking away from the dry-as-dust rules and insisting rather upon their practical application in the laboratory and in the everyday concerns of life, the teacher is incidentally in position to help develop individuality and initiative in the work of the student.

The standardization referred to by Professor Raymond deserves attention. A few years ago a committee representing the four leading national engineering societies recommended the adoption of fourteen rules on standard abbreviations, symbols, etc. Only one of these societies, the American Society of Civil Engineers, has adopted these rules in practice. The Mining Engineers have accepted all of them with one exception, whereas the Mechanical Engineers and the Electrical Engineers have inserted them in their respective style sheets. The Society of Civil and Mechanical Engineers of England had the matter of standard formulas up for discussion a few years ago, but has not as yet come forward with any definite recommendations. As the engineers themselves are undertaking this problem, the teacher of English will be spared entering this field of standardization.

In conclusion, let me call your attention to a careless use of terms pertaining to English on the part of some engineers. In a well-known book on specifications and contracts the author urges the writers of such documents to "avoid rhetoric." The absurdity of this advice is apparent when we remember that rhetoric is nothing but the expression of one's thought with the greatest possible efficiency. A due regard for rhetoric in the preparation of specifications and contracts will prevent unnecessary misunderstandings and consequently, costly lawsuits.

Professor H. Wade Hibbard: I wish to call attention to four points: (1) I would like to take up the gauntlet just cast down by the first engineering professor that started me in my engineering instruction. I believe he said or intimated that there is no college in the country where engineering students could be placed side by side with arts students in English and be equally successful with them, and that there is too much jealousy in our faculties. At the University of Missouri we are fortunate in having the most cordial relations between the professors of English, with their subordinates, and the faculty of the School of Engineering. In fact, at the present time they are members of the faculty of Engineering. They meet with us for the discussion of English and we are all in the heartiest accord.

(2) I believe that English is not only a means for engineers to express themselves in engineering reports, but it is also a means for engineers, as members of a profession, to take their stand with the members of other professions as cultured men of the world. We all, and our students especially, need a training in English as a means to this end.

(3) Last year our engineering faculty passed a resolution that right through the engineering course, up to the time of graduation, any student, who shows in his written reports that he is deficient in English, is to be reported to the dean. The dean confers with the department of English as to what further need there is for instruction of that particular student in English. He may be required to take more English, even though he be a senior.

(4) The University of Missouri has abolished entrance direct from high school to the School of Engineering, and requires two years' preparation in a college of arts and sciences. We believe, therefore, that the matter of English will take care of itself very largely; that it will be much better handled than in the past, because the students will come to us after two college years under the strict supervision of those who are interested in good English.

Mr. H. A. Gehring: I would like to ask if any of our engineering schools, or college of liberal arts has adopted the phonetic or simplified spelling. It seems to me that in connection with a consideration of teaching the student to express exactly what he sees and knows, there should be some discussion as to the advisability of spelling words as they sound.

Professor J. J. Flather: Mr. President, from my experience, I conclude that most young men do spell phonetically.

Professor Raymond makes a very terse remark to the effect that "the language code, that is, spelling and grammar, are hardly to be taught in either case, but are to be mastered with the development of knowledge and judgment and the spirit of good workmanship." We should not be expected to teach spelling and punctuation in our engineering classes. It is a matter that must be taught better in the preparatory schools, and then additional efficiency and proficiency must come from the written exercises as they may be given in the college. I appreciate the additional papers on this subject. We, as engineering teachers, must give more attention to the teaching of English. There is a reproach attached to our engineering graduates, largely because they cannot express themselves properly in a written document. I remember that, over fifteen years ago, a request came to us for a graduate of the mechanical engineering department. The only limitation imposed by that request was that the applicant should be able to write English correctly. The position was that of assistant to the works manager who wanted a man that could express himself properly in English. There were twenty-six men who graduated that year but I could not recommend any one for the position. Conditions are improving. It used to be that one hour a week for a year was devoted to the study of rhetoric; now at the University of Minnesota we are giving four hours a week for a year to the study of English. I like Professor Raymond's suggestion that it would be a very good plan to have one term in the junior or senior year supplementing that. After a man has acquired a technical vocabulary and has absorbed a mass of general knowledge, articulation with the English teachers would be very beneficial.

It is a part of my duty to teach Contracts and Specifications to all the senior engineering students. In this the men present contracts and specifications covering the work in hand. Many of the clauses in these specifications are ambiguous or may be interpreted in two ways. The English is poor and the sentences lack conciseness. I have often thought that it would be a good plan to co-operate with the English department in this work. A closer articulation with the English department in several lines where written exercises are required, would be beneficial. We teachers of engineering should not be satisfied with simply teaching engineering subjects, but we should co-operate with the English department in training men to use language correctly; to express themselves intelligently; and to present a report or draw up a specification which will indicate that the writer is a man of education. This may be done by having the English taught in the academic department, or by having the academic department set aside men to teach the engineering students; or the engineering college may have its own instructors in English. That is a matter of detail. In the University of Minnesota the English department delegates its teachers to the engineering college and there is a close co-operation. Our students are admitted to the College of Engineering on certificate in all subjects except mathematics and English. Within the last two years the faculty has passed a rule that every applicant for admission to the engineering school must pass a satisfactory examination in English, and if he cannot do that, even though he may be proficient in all other subjects, he must go back and take additional work in English before he can enter the engineering college.

Professor J. C. Tracy: I agree with Professor Flather that one of the most important things to be considered in this matter is co-operation between the instructors in engineering and in English. An experiment that has been tried in the teaching of English in the Sheffield Scientific School is this: At the beginning of the second year the student reports to his professor in engineering for the assignment of a subject of a composition. After informing himself upon the subject and preparing an outline he reports to the instructor in English for a criticism of the outline. Next, he writes his theme and submits it to the instructor in English for criticism. Finally the composition is submitted to the instructor in engineering for criticism from an engineering point of view. The best of the themes are filed for future reference, and the very best ones are either read before the student engineering society or published in the engineering papers.

Professor C. M. Young: We need co-operation not only in written work but in oral recitation work, for the reason that the student needs not only ability to transcribe into formal written English, matters which he has first thought out roughly, but to think accurately and properly in the first place. That is, he should be able to produce at first writing what is practically his finished report, with such corrections as may afterwards be desirable, and it ought not to be necessary for him to transcribe it from poor into good English. In order to attain this end we must create a habit of the use of good language. It is unfortunately necessary to combat in the schools the lack of good language training in the home. The language which one learns in his home and among his associates is that which almost always becomes his natural language through life. Therefore it is all the more necessary that we daily, in association with students, insist that they use proper language. I use the expression "proper language," meaning simply, correct, suitable. When the students leave school they will not be instructed in the use of language but their training and ability will be judged by their reports, and these will not be sent back to them for correction. While we have the men in school we can, to a very large extent, help them to use language to impart their own thought and to give good impressions of their ability.

Professor Wm. T. Magruder: I can not agree with the statement that we can not teach spelling and grammar in our engineering courses in college. In my opinion, it is our duty to do so. Engineering professors err when they accept reports which are full of poor spelling, bad rhetoric, and worse composition, and pass such work as acceptable towards graduation in engineering. I dislike the idea of a double standard in English for engineering and academic students.

The attention of the Society is desired to three pieces of educational practice which have been going on for a number of years, and which have been proved to be eminently satisfactory and worthy of careful consideration for adoption at other engineering colleges. One of these is at Northwestern University, where all freshmen are tested in both spelling and punctuation about ten days after entering college. Those found to be seriously deficient are required to enter a sub-freshman class which meets once a week, and to remain there until they show a marked improvement at the monthly written test. Thus the class gradually grows smaller until there is a one per cent. remainder that seems actually unable to learn to spell. No credit is given for freshman work in English unless the deficient student has attended the elementary class regularly. Professor J. Scott Clark states that "about sixty per cent. of the graduates of our best secondary schools are seriously deficient in spelling or punctuation or both."

The second instance is at the Kansas State Agricultural College, where they have revived the "spelling bee," and offer each year a silver loving cup, to be competed for by the members of the literary societies, and to be awarded to the society proving itself the champion. A marked improvement has been noticed in the spelling, not only of the competing students, but also of the rest of the student-body, apparently as a result of their attention having been called to the matter of accurate spelling. Professor Lewis H. Beall is compiling a spelling manual which will contain about three thousand words which are frequently misspelled and which observation shows that high school and college students need to learn how to spell.

The third case is at the University of Colorado where a certain amount of summer work in the reading of high class English literature in science, history, poetry, drama and fiction is required. After a young man has read books of the kinds specified, he has obtained visual pictures of a larger vocabulary than he had before, and hence has a broader training in English.

I desire to emphasize the statement that a student's training in accuracy for his engineering professional work should begin in the grammar school with an accurate study of words and sentences, and should be continued through his high school and college courses.

Professor Flather: I agree with Professor Magruder in that I believe a technical instructor is at fault if he does not correct every error he finds. But when a boy reaches eighteen or twenty years of age without having learned to spell, then we cannot make a good speller of him. We can and do improve him. We make some progress; but I have yet to find a man who has become a good speller under the influence of the instruction in the engineering college.

Professor Magruder: Statistics of Northwestern University deny that statement.

Mr. Kent: In a paper* presented a few years ago I showed that two-thirds of the errors in spelling can be eliminated during the freshman year, that is, one hour a week with the freshmen for a year removed two-thirds of the spelling errors. I know boys that used to be poor spellers that are now good spellers. Spelling can be taught in the technical school.

Dean G. C. Anthony: Professor Earle states in this paper that the teachers of English in technical schools should be engineers. I used to believe this as well as that teachers of mathematics in engineering schools should be engineers. I do not believe now that it is at all necessary. The English faculty in the engineering department of Tufts College is organized with Professor Earle at the head. He is a man who took his master's degree in English and specialized in Anglo-Saxon. It was his desire to teach the latter when he came to Tufts

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* Proc. S. P. E. E., Vol. XVI, pp. 74–82.

College, but he was disappointed in this desire and was obliged to teach a variety of things. Finally I asked him to take up this work, because he had those characteristics which enabled him to get in touch with other departments and he succeeded in his work because of this spirit of co-operation. Of the other two men in the department, one had made a specialty of the drama; the other one was prepared particularly to teach English in the secondary schools. Those men work together as a unit with the engineering school. And I believe the success of the work is due to this and not to the fact that the teachers are specially prepared to give this particular kind of instruction.

I have during the past year on one or two occasions said something about the importance of English to students. The attitude of the students toward it is as if they would say, "Of course English and mathematics are important." There have been many times when I have had to defend English. But I do not have to do that with the engineers. They elect it in their junior courses and afterwards in their senior years.

Professor Magruder (by letter): I wish to call attention to a recent issue of SCIENCE,* in which Professor James R. Angell of The University of Chicago calls attention to the fact that, of the fifteen units required for admission, a student must present three units in English, seven units in one or more of five groups (ancient languages, modern languages other than English, history, mathematics, and science), and five units in any subjects for which credit towards graduation is given by the approved school from which the student receives his diploma; Professor Angell calls particular attention to the fact that a student need not have taken work in three of the five groups above named, provided he has enough work in the other two groups, and that the contents of the five remaining units are left entirely to the secondary schools. Entrance on these conditions is confined to approved secondary schools which can be depended upon to graduate no boy who has followed a freak course of only languages, or one of only English, mathematics and the sciences, and who has omitted all other humanizing subjects. The requirement of The University of Chicago that "there will be no admissions with condition under the new plan" is one which the engineering colleges might well consider.

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* N. S., Vol. XXXIII, No. 860, June 23, 1911, p. 945.

Professor W. A. Hillebrand (by letter): The importance to any man of being able to express his ideas in clear and forceful language is not a question for argument, and yet I am, in general, opposed to formal instruction in English for students in engineering. In the first place, it is true of professional students in general, that, as a body, they object to taking work outside of their own or allied departments. Regrettable as this spirit may be, it is nevertheless a factor to be reckoned with in any organization aiming to produce results and not merely to go through the forms. In the second place, the teachers of the various prescribed subjects in the professional course have it in their power to insist upon habits of clear thinking and expression with an effectiveness which is denied to the teacher of formal English whose students come to him under protest, with a feeling that they are being imposed upon in being forced to devote time to something which has no part in their purpose in coming to college. Mere continuance in formal instruction to people who for twelve years have been reared on such a diet is not so important as it is to insist that they maintain the standard in English of which they are capable on entering the university.

At Stanford our freshmen come to us able to express themselves in a clear, straightforward manner, but also thoroughly imbued with the notion that the exercise of such ability is not called for in their profession, with the result that their first reports are often loosely and carelessly written. After they realize that such work is not tolerated, and after being obliged to rewrite, a marked improvement follows. The same is even more true of the students who enter our courses in the middle of the junior year, after having relaxed for five semesters. In most technical schools the students in electrical and mechanical engineering, during two or sometimes three semesters of their course, submit from two to three reports a week, in the preparation of which exceptional opportunity is offered for training in clearness of thought and expression, the very end that is sought through the formal teaching of English. Each of these reports should be scrutinized as closely and criticised as rigorously for its arrangement, expresson, grammar and spelling as for its technical features. It may be objected that the report readers lack time to do thoroughly all of these things. Is it not hypocritical then, for the teacher of engineering to require his student to devote time to the study of English composition, for the reason that facility in the use of the language is essential to success in his profession, while the teacher or his subordinates will accept, in so far as English is concerned, anything which the student chooses to hand in? For instance, I know of one technical school of high standing wherein enthusiasm for breadth of training has extended the prescribed course to five years. Yet one of their instructors who has a great deal of report reading to do, tells me that in the majority of cases he has not time to read the body of a report but is forced to confine his examination to the log sheet, curves and computations. Another department, similarly inspired, was ready to accept a thesis of over a hundred pages, so poorly written that an acquaintance by whom it had been examined, said he would be ashamed to put his name thereto.

If the proper use of English is an essential asset of the citizen and professional man, we have it in our power to materially forward the good work by making it equally essential to success in his college career.

Mr. H. A. Gehring (by letter): The best method of teaching English to future engineers or to anyone else, is so wholly a function of time, with all that time implies, that we need not be discouraged if no uniformity of opinion is expressed on this subject, or if no general scheme is adopted. So diversified are the conditions at our various engineering schools, so potent are the factors of the age, location and prestige of the institution and the past growth by which each present relationship of English to the curriculum has been attained, and so heterogeneous are the mental make-up of the students and their adaptability toward proficiency in English, that no two schools would develop their best efficiency under a common code. For these reasons the ultimate methods of dealing with English must of necessity be determined separately by each school, even by each professor, and again in the last analysis in reference to each individual student or group of students of approximately similar qualifications.

If I have rightly interpreted the papers read before this Society on the subject in question, together with the valuable discussions on the same, I conclude that none of the writers has claimed to offer a specific, appreciating the impracticability of such a thing. Each writer has told of his own experiences and results, and if these could be plotted on cross-section paper and a probable prognostication curve deduced, this curve would reflect the results which he hoped to attain by his suggestions for the future. If your experience-result curve were plotted on paper, would his probable future extension fit your curve? If so, you would doubtless incorporate his experience and suggestions into your own; if not, the adoption of his suggestions would not meet your conditions and your result would not be as substantial as it should be after a year of trial and effort.

I want to emphasize strongly one point on which I do not think that enough has been said, and which seems to me to be of fundamental importance and indeed the first and most logical step that should be taken. If the student is to use good English it is imperative that he be continuously in an atmosphere of good English while he is acquiring the habit. We can not assure for him that atmosphere before he reaches our engineering schools, whatever conditions we impose upon our secondary schools in the matter of teaching methods, but we can insist on having in our engineering schools professors and instructors who themselves will be continuous examples of the proper use of the English language. To require reasonable proficiency in English of our faculties is to establish a procedure which no extent of time will ever cause to be changed. Hence this should be the first step toward teaching English in technical schools, since what the student most needs is the constant association with a faculty of men themselves proficient in the English language. Then, whether in recitations, or in written papers, or in oral presentations, the student knows that his use of English is being observed and that his work will be rated accordingly. Daily contact with users of good English is a more potent educational factor than a first-class English course not backed up by a proficient English-speaking faculty, and such daily contact with proficient men is the only training which a student should need and receive when he has advanced to the grade of a technical school.

Most of the suggestions made by previous writers have been toward securing a first-class course or method in English: my suggestion is to insist on a first-class English-speaking faculty and then to let the course take care of itself. This suggestion seems to be in accord with the views of Mr. Hamerschlag, who says: "In my judgment, English training does not belong in the school of engineering. It belongs to the secondary schools," to which I would add "except in as far as it results from daily contact with an engineering faculty in which every man by his own example can stimulate in the student a desire to speak good English, write good English and read good English," which Mr. Hamerschlag doubtless implies.

That there are big objections to the adoption of my suggestion, is as evident to the writer as to the reader. Personally I do not think that the present conditions warrant the introduction of an English course into our technical schools, nor of a housecleaning amongst the faculty to weed out those who may be more or less deficient in English while exceedingly proficient in their branch of engineering. That the ability to speak and write English correctly is an asset, no one will deny. If some active steps toward providing this ability are inevitable in our technical schools, I maintain that more real and genuine good will be accomplished by keeping the student in an atmosphere of good English for four years, than by teaching him English according to some prescribed course.

A systematic course of lectures before the engineering students either by their own faculty, or by members of the faculty of Arts or by outsiders, should prove of great value in teaching students to observe and appreciate good English.

Mr. Harwood Frost (by letter): In offering any discussion on the papers of Professors Earle and Raymond, I am actuated by a personal interest in the subject of technical English, but I can not speak as one who has had to face the difficulties of teaching the subject in the class-room.

From Professor Earle's paper, I draw the conclusion that the object of the course in engineering English, as conducted by him, is to develop in the student the ability to think clearly and to express his thoughts and actions, and his descriptions of objects, both orally and in writing, in language that will convey his meaning correctly to others. If, as James Russell Lowell says: "Thinking is the highest aim of all education," Professor Earle's object is fully justified.

The main difficulties in the attainment of this object lie in the student's lack of appreciation of the importance of his English studies and in the lack of harmony between the purely technical, and what might be called the cultural, departments of the institution. In a letter I received recently from the dean of one of our largest engineering schools, he says: "One of the most perplexing problems among our universities at present is getting any sort of connection or sympathy between the English departments and the engineering schools." This must certainly be so if the teaching of English to engineering students is left to an English department conducted by non-technical instructors. I know that this lack of harmony, in some schools, extends to the degree of greatly lowering the standing of the English departments in the opinion of the students, and with this comes a certain contempt for both the instruction and the instructors. It is there, although the relations between the students and their instructors do not permit the student to show it. He is in the position of the witness who was accused by the judge of showing his contempt of the court. "No, your Honor," he replied, "I am trying my best to conceal it."

The student comes to college from some school where the teaching of English in one way or another has been inflicted upon him for years, and he thinks he should be through with it. He goes to college to study "engineering." A prime requisite, therefore, it would seem to me, would be to show the student, as early in his course as possible, that English, as it is to be taught him, is a part of his necessary engineering education, and thus to cultivate a respect for the course, and an interest in the work, which will, in turn, create an ambition to do as well in that study as in surveying or testing of materials.

This must, of course, be backed by the actual fact that English *is* a part of the engineering instruction, and while Professor Earle says nothing in regard to the cultivation of a proper respect for the course, he seems to have solved the problem of a connection between the English and the engineering departments, to a great extent, at least, by a system of co-operation that injects the study of English into the various technical courses, and by a consideration of the efficiency of the English instructor. This co-operation, as Professor Earle says, has numerous and very important possibilities, and suggests the question whether a system of co-operation could not be developed to reach beyond the limits of a single institution.

As to efficiency of the instructors in English, there is no doubt that this is too little considered by many schools. That anybody can teach English, is a general idea, but it takes a man with a special training to teach railway engineering, for instance. Therefore, a cheap person—the second cousin of a trustee, perhaps—is hired for the job, at a small salary. The fact is, the mere teaching of rhetoric from a book, and the writing and correcting of "themes" is *not* teaching engineering English. When a technical journal hires an editor, to a certain extent it hires a man who should be teaching English and technical writing to students of engineering. If the standard of efficiency were more like that of the technical editor, and the pay was in proportion to the requirements, teachers of ability could be obtained, who would make the course an actual feature of the student's engineering education, and not merely an appendage that has to fight for a position in the curriculum amounting to about three hours a week.

A point of importance brought out by Professor Earle, that is too often overlooked, and which supports the necessity for efficiency, is the fact that *every* teacher is, in a way, a teacher of English; that no teacher in the institution can help exerting some influence, good or bad, over the student's use of his native tongue; that the training that the student gets depends not upon the teaching of English alone, but upon the general attitude of the faculty toward the subject. This is so evidently true that no comment is necessary.

I hesitate to venture any criticism of Professor Earle's paper, but there are a few points omitted that I, for one, would be interested to hear about. I would like to know if any special attention is given in his course to the study of words and their use and abuse, to the extension of the student's working vocabulary, to the cultivation of his powers of observation, to his improvement in general conversation, to the cultivation of some system of methodical study, to the development of concentration, to improving his methods of reading, to judging and criticizing the literary works of others, and a few kindred matters, all of which I consider should be included in a complete course of engineering English and technical writing.

Some of these matters are taken up in Professor Raymond's paper, which I have read only in an incomplete summary. From that reading, I would judge that Professor Raymond gives early attention to the elements of language and to words and their proper meanings. Nothing could be more important that this as the basis of the study of technical writing, in which accuracy of description and sentiment is so essential. This is evident from an inspection of the most casual writings of technical graduates, very few of which could be reproduced in a high-class literary journal without considerable editing of a very elementary nature. The ignorance of many graduates of the correct use of words is also noticeable in specifications and correspondence, as well as in ordinary conversation. In two printed sets of specifications that came to my notice, and which were written presumably by engineers, were the expressions "demoralized rock" and "wholesome earth," and a certain well-known engineer and employer of labor told me of an applicant for the position of foreman who claimed that he had an "abdominal will." As to the profit of this study, an English writer has said: "In a language like ours, where so many words are derived from other languages, there are few modes of instruction more useful than that of accustoming young people to seek for the etymology or primary meaning of the words they use. There are cases in which more knowledge of more value may be conveyed by the history of a word than by the history of a campaign." If this is true of ordinary words, it is even more true when applied to technical terms.

Professor Raymond goes on to say that the best basis for organizing the study and practice of written composition seems to be that of purpose. This but follows out the general principle that the first essential to success in any work is an aim or motive; and this early institution of a worthy purpose in the study of English should do much towards meeting one of the main difficulties in making the student think for himself—that of overcoming his lack of appreciation of the importance of his English studies.

Professor Raymond also gives attention to observation. This I would consider a very important element in teaching English. No one can advance in learning without some cultivation of his powers of observation. Everybody has this faculty to a certain degree as it is through it that the infant obtains his first knowledge of things. In its strictest sense, observation does not necessitate any reasonings of the mind, or drawing of conclusions from what is observed, but as it is hardly possible for any thinking man to come into contact with a new idea without making some swift mental reflection upon it, Professor Raymond's system of "Technical Reports" would seem not only to aid the faculty of observation, but also to reduce these involuntary mental reflections to definite form, from which the student can ultimately derive considerable profit. Without some such compulsory and properly guided stimulus, the student is much like the man, who had eyes but saw not, who had ears but heard not. The preparation of these reports would also seem to lead to concentration of thought, so necessary to the engineer, and to the cultivation of judgment of value and criticism of literary works, on the part of the student, that will be of benefit to him throughout his entire professional life.

Professor Felix E. Schelling (by letter): The most striking thing in Professor Earle's able paper is his substantial agreement with what I should consider the best usages in the teaching of English now in vogue in our better colleges. As a matter of fact we have been doing most of the things which Professor Earle suggests here at Pennsylvania for many years, but have not been aware that we were doing anything at all extraordinary. It strikes me, however, that Professor Earle's impressions of the state of English elsewhere are certainly not quite those which experience seems wholly to warrant. For example, I do not know where there is anyone who holds that English "is the last bit of salvage from the arts course remaining in the engineering school and . . . the only means of true culture in a curriculum otherwise hopelessly practical." There may be people who believe such things; I have not met them. Again, I do not find it a matter of great novelty that students of English should be required to "put their ideas into exact language," that they should "reason on things without the objects present to suggest, guide, or correct them," that they should be taught that there are various kinds of discourses adapted to different purposes and to different sorts of minds, and that they should be taught how to treat subjects "completely and accurately." These seem, all of them, to be the very bones and sinews of any rational teaching of the subject. In looking through this paper with a genuine desire to profit by the experience of one who is so devoted to his work, I am glad to find myself so completely in agreement with most of Professor Earle's propositions. For example, I agree that a careful "consideration of the needs of the profession—I may interpolate of any profession—should lead to an elementary course as broad and as thorough as that given to students in Arts." I also agree with the statement that "special drill in technical writing is not (and should not be) intended to take the place of other work in English." Here are the two main propositions in the matter. Let us hold to them as most important. First, *students in engineering should have as much English, and the same kind of English, as that given to students in arts. Secondly, special drill in technical writing must not be allowed to take the place of that general drill which is necessary to all, however advisable it may be to add specific training in additional and elective courses.* In these basic principles Professor Earle and I are at one.

Without going further into details in which I agree, and they are many, I should like to note what I find in this paper that strikes me as novel. The idea that a teacher of English should be likewise an engineer strikes me as novel in the extreme. I would suggest that the converse would be better—that we demand that every engineer be capable of a reasonably accurate use of his mother tongue. But to return to novelties: one of them I note is the restricting of that larger range of subjects which must occur to any intelligent teacher to the narrower range of subjects in which the student is constantly working. Does a boy, in training to become an engineer, really find a greater interest at all times in engineering subjects than in others? Professor Earle finds it "surprising how much interest freshman engineers will take in writing stories." In this they are precisely like other freshmen, and will Professor Earle say that this "interest" is to be increased by restricting the range of this story-writing to "engineering stories"? Another novelty which I note is the carrying on of the consultation in the drawing room or other laboratory by means of a committee consisting of two instructors and the student in the case. The getting up of any report in writing or any oral recitation is made up of the two elements, the thought and the expression. It is found ordinarily to be quite sufficiently difficult to keep the student to his subject without confusing him by a second line of thought. I can not see how, pedagogically, any real value can come from combining two processes which, after all, might be more effectively accomplished separately.

I am thoroughly in favor of co-operation in the instruction of our students. I am thoroughly in favor of having our younger instructors learn from their elders. Professor Earle's system of an apprenticeship of one year for the newly appointed instructor, before he is entrusted with a class we have here at Pennsylvania, though we usually make the apprenticeship two years. The difficulties with collaboration are manifold where the curriculum is complicated; and it may be questioned whether a close attention to the methods of other members of the department, especially seniors, from whom favor and appointment comes, may not result as frequently in curbing originality as in increasing effectiveness. We have been accustomed at Pennsylvania to welcome every new method suggested, to give any young and enthusiastic man an opportunity to try himself out in his own way, to hamper him as little as possible by precept, or even by example, and we have found in the broader outlook that has given the department as a whole what we believe to be a very material gain.

In conclusion of this subject, I should like to present the topic on broader grounds. Obviously, in the education of any student there are two things to consider, the education of the man and the education of the engineer, the architect, the doctor, or the lawyer—whatever he may propose to become; and *the education of the man must come first, or it will never come.* The ends and aims of technical education are different from the ends and aims of that liberal education, however derived, that must precede it. I am not a stickler for Latin, Greek, mathematics or anything else as a means of liberal education; there are many such means; but I am a stickler for absolute freedom in such subjects, when used for liberal education, from all technical and ulterior considerations. I should draw a distinct line between pure mathematics and applied mathematics, and I should say that mathematics is best taught as mathematics first, and in its applications secondly. I should say that the culture value of a pure subject was infinitely above that of an applied subject. I should say that the intrusion of application in a subject would proportionately destroy its value for culture. It strikes me that the question of "Engineering English" is a very simple one. English is our universal tool; without English we can do nothing. It is as essential an equipment to one as to another; it is as necessary as the multiplication table. The difficulty with "Engineering English" is the desire of those in charge of engineering education for a short cut. The English department of Pennsylvania is not permitted to give as much English to engineering students as it gives to other students or as much as it recommends. Engineering students are not permitted, by reason of the stress of other work, to take electives in the subject. It is the belief of this department that English should be taught in its purity to all students alike, with a special emphasis to those who take scientific subjects because they have not the advantage of those helps which the study of the classics could give them. This department would like to strengthen to the full the required English for engineers, and it would like to have an opportunity to offer electives in English upon the basis of that preparation. It would recognize in full the advantages of technical training in the case of instructors put in charge of these advanced subjects, but it feels that English, like all other subjects, is a matter of expert knowledge. We would go to our friends, the engineers, for help in building bridges; we should like them to come to us for such help as we can give them in the teaching of English.

Dean J. D. Newton (by letter): The writer has taken more than passing interest in the papers of Professors Earle and Raymond, because he has frequently discussed with the latter, as a member of the same faculty, considerable of the subject matter of both papers, and because the relation of English to the other work of engineering courses is a live issue in the institution with which he is now connected.

The authors appear to be agreed, and no doubt many others are in substantial agreement with them, as to some of the methods that ought to be employed in teaching English, the term being used in the sense indicated by Professor Raymond. One might very reasonably infer from the papers that some sort of departure from traditional procedure, some sort of reform, is advisable, not only in English but more generally, if it be assumed that the majority of technical graduates are given to looseness of expression and thought. Undoubtedly, the estimate placed by an institution or teacher on the relative importance of English or any other subject will suggest the nature of the courses and the methods of instruction; and the attitude of students toward particular courses will in general be regulated by the institution's interpretation of the requirements of the twentieth-century engineer.

Both papers invest an ideal, to which the technical graduate should be an approximation, with the ability to acquit himself creditably through exact thought and expression. The special drill in technical writing appears to be a substitute for "the training in exact expression required by the study of Latin which gave the students thorough drill in exact thinking"; to the lack of such discipline is ascribed the "loose thought and still looser expression of the majority of technical graduates." On this assumption, might it not be well to consider the advisability of suggesting to prospective engineering students, though not requiring of them, the presentation of some units of Latin for entrance instead of certain accepted equivalents. Might not the revival of Latin, as a preparatory subject, help to eliminate, or at least to mitigate, the defection mentioned. Our faculty (recently organized), though fully cognizant of the claims advanced for other preparation, has recommended the substitution of Latin for certain of the more usual preparatory subjects. There is, however, no intention of transferring Latin from the optional to the prescribed list of entrance units. Our entrance requirements follow the definitions and formulations of the Society's committee, and most of our matriculants are high school graduates with varied preparation.

Our present tentative engineering courses were outlined to meet our interpretation—which seems to differ little from the Tuft's idea—of the purpose of contemporary engineering training. The courses were not outlined for the special purpose of featuring English to the detriment of anything else, but the art of definite and correct expression was considered to be an essential qualification of the technical graduate. Some comment on the methods employed at present, and contemplated in the future, may be of interest, and is submitted as a contribution to the discussion.

The instruction in freshman English is entirely dissociated from that in the college of arts and sciences, a special course of three semester-credits being given throughout the year. The prospectus is made to say that considerable importance is attached to English (as well as logic, German, French, and economics), that the work is designed to accord with the other work of the courses, that the requirement will not be considered fulfilled by the satisfactory completion of the first year's program, and that a supplementary course of indefinite duration will be provided as a corrective for delinquency in the succeeding years. Freshman instruction is preceded by a lecture on the purposes of the engineering courses. Through this lecture is conveyed the faculty's appreciation of the value of English. To the English department is committed the task of acquainting students with the ways and means of using the library to advantage. A text book is used and instruction in rhetorical theory given. The written exercises are based on ''the lives of distinguished scientists, assigned readings, and visits of inspection.'' A search through the sources of information for material dealing with the life of a scientist means some little insight into the times of the scientist. Some of the ''assigned readings'' are from current technical literature, and synopses of certain articles are required. The ''visit of inspection'' is sufficiently elastic to be applicable to a drafting table, leveling rod, steam engine, or factory. Following the freshman year, the inspection trip provides an excellent medium for the combination of rhetorical and technical instruction. Of course other results, possibly equally as desirable as the acquirement by the freshman of the art of definite and correct expression, are expected to follow the use of these methods, but the desideratum, in so far as the methods relate to English, is the cultivation of the art, and a realization, on the part of the student, of its value and importance to technical men.

To further the effort at correlation, a set of instructions to govern all written work, is supplied to the student at the beginning of the freshman year. All work submitted in satisfactory form during the year, is placed on file, some of it to be retained permanently.

Under our proposed system, students, who have not had equivalent experience, are required to spend the summer in some gainful occupation related to constructive or productive engineering. A written report, embodying all the features of the technical report described by Professor Raymond, and based on the work, is required. The previous equivalent experience does not relieve a student from the obligation, but may furnish a basis for his reports. All such reports are to be deposited in the departmental library, but are not regarded merely as consignments to the depository. They are assumed to be contributions of such value and importance as to be read intelligently to others, printed, and consulted as reference material. All conferences relating to these papers will be assigned to engineering instructors.

Of course the summer work is intended to contribute to the student's general efficiency, but the attitude of the instructor concerned, toward the report, will determine the degree to which the student's mastery of English may be helped or hindered by written exercises of this nature. If the instructor be one of the unfortunate majority heretofore mentioned, his own efficiency is thereby limited, whatever his attitude.

While the objects to be attained by such courses as logic, economics, the law of contracts, the writing of specifications, are other than the development of the student's latent powers of correct expression, all can be so shaped as to lend themselves readily to such development, through oral and written practice. Increasing proficiency, through practice, in the use of English, should be expected to a degree paralleling the increasing facility expected in, for instance, drawing or freehand lettering.

The success of the methods outlined will depend on a general understanding of the purpose of engineering instruction, and on organized co-operation—not unrestrained individualism—to the end of helping students toward the acquirement of the art of correct expression, without detriment to any of the other well recognized essentials of the graduate's equipment. The writer takes this opportunity of commending the papers of Professors Earle and Raymond, for he believes that some such system of co-ordination and co-operation will promote efficiency, not in English alone, but in everything else.

Professor Geo. C. Shaad (by letter): A considerable portion of the work of the practicing engineer consists in the preparation of written statements, varying in form and extent from a simple business letter to a complete report on some intricate technical subject, and inability to do this class of work well has undoubtedly been a handicap to many in the profession. A part of the student's time, then, should be devoted to this class of work and it is a matter of consideration of the total time available and the relative importance of the different subjects included in the course, as to just how much time can be given to the writing of papers. That all papers which are prepared should receive careful criticism, both as to material presented and composition, goes without saying.

One of the duties of the department of English, then, should be to inform the students as regards the collection of information and material relating to some particular subject, and to give instruction regarding the efficient use of reference libraries. The careful selection of material and its logical presentation should receive considerable attention, and the mechanical features of a manuscript report should not be neglected. The department of English can give some time to the practice of gathering information and preparing papers, but it appears to me that the greatest good can be accomplished by having careful co-operation of all of the departments with the department of English, to the end that all written papers, whether in the form of long technical reports prepared for the department in which the student is enrolled, or reports on routine laboratory work, shall be criticized along the same lines as they would be if they were formal exercises in English. For the best results it is essential that all instructors, as well as the students, be interested in the matter of good composition of engineering papers.

While the laboratory reports present one form of exercise, there is much to be gained in requiring students to prepare longer papers where the matter of collecting the information is thrown more upon the student, and where the matter of good presentation is perhaps not as clear as it is in the laboratory work. Our students are required to prepare four such reports during their course and in addition to this we consider the preparation of their theses as a final exercise. We believe that the results obtained from this particular work more than repay for the time required for it.

Dean J. J. Clark (by letter): I recently received a letter from a practicing civil engineer, from which I quote as follows:

"In the beginning of my experience as an engineer, one of the hardest problems I had to contend with was to write an intelligent, comprehensive report upon any engineering matter that came before me, and I find from my acquaintance with engineers in general, it is a common failing among them. This is largely due to the fact that this feature in the education of an engineer does not usually receive any attention at school, or, at least, sufficient attention, to give him an adequate idea of this field of engineering, and today, it is to my mind, as essential that he be prepared for this as for many other things he is called upon to perform. . . . I am satisfied that many men who might rise to something higher, are at least hindered, if not precluded, by a lack of appreciation of the possibilities of this field. Writing intelligently is largely a personal equation, but men who do not write have the possibilities within themselves, if their minds were prepared for the work.''

As I understand it from reading Professor Raymond's paper, it is such conditions as these that he desires to remedy, and, in so far as I can see, his system, if intelligently carried out, will do this. I note, however, that Professor Raymond does not lay much stress on the feature that interests me most, which is, criticizing of the student's written work. While, to be sure, he states that the papers prepared by the students are criticized, he does not state who does this criticism, nor the nature of it. In my work, I do not pay so much attention to grammar, spelling, punctuation, etc., as to style. While permitting, and even encouraging the individual writer to preserve his own general style of writing, I endeavor to point out to him wherein his statements are not clear, and where he has ``shot over'' the heads of his readers, so to speak. Of course, he is required to present his thoughts in a logical order, and he is required to conform to our rules regarding spelling, capitalization, use of symbols and abbreviations, and other typographical features, in so far as it is possible for him to do so. I do not think it feasible to evolve a general standard that will be used by all engineers and textbook writers, as suggested by Professor Raymond, and this opinion has been strengthened within recent years by the action of the American Institute of Electrical Engineers when it adopted its present standard. If, however, the system as outlined by Professor Raymond be adopted by any college or engineering school, and carried out conscientiously, it should go a long step towards remedying existing defects. It would be a good idea for each engineering school to have some system of punctuation, capitalization, use of symbols and abbreviations, etc., and this should conform, in so far as is practicable, with the forms in most general use by the best writers. Each student should be required to conform to the standard, and even if he has to change somewhat in minor details later, he will have been taught to be systematic and thorough.

Mr. Charles Carroll Brown (by letter): I feel honored in being requested to discuss Professor Raymond's paper and thus to renew my connection with the Society, of which I was a member in its early days. I contended then for a broader education for engineers, and have often deplored the early neglect of English in the courses of study in engineering schools. I am more than glad to see that this defect is being corrected and that such practical work is being done as that indicated by the papers of Professors Earle and Raymond.

The fact is that the engineer often fails to attain his ends because he does not know how to state them and the processes by which they can be reached. He is the natural developer of most of the plans for utilization of our natural resources, for new lines of transportation, for improvement of our physical conditions, but the details of his profession are, at least in his early life, so absorbing that the tendency is away from rather than toward effective self-expression in the mother tongue. He therefore needs, as I have often said before, even more training in practical English work than the candidate for any other profession.

My work for much of the time since I resigned a professor's chair has been in a field where this lack of ability of the engineer to express himself shows most prominently. It is most difficult to obtain even a bare description of an engineering work which will be at the same time accurate, clear, logical and readable. It is almost always necessary to infuse another personality into the story, with some detriment to correctness and loss of personal touch with the work, in order to get the article into such shape that it can be read with appreciation by the ordinarily intelligent engineer. I am glad to say, however, that, due no doubt to the good work of the gentlemen who have written these papers and others in the same line, the words ''almost always necessary'' are becoming more out of date each year, and may before long be substituted by ''seldom necessary.''

After fifteen more years of experience, not in the college but in the practice of engineering and in business in which an engineering education is an essential, I am quite as strenuous in my demands for a thorough general education as I was in a paper before this Society at its Springfield meeting, and would add to it a statement of my belief that a very essential element in this general education is a thorough grounding in the history, structure and practical use of the English language. While the average engineer scarcely knows the elements of technical logic, he is so thoroughly trained in its practical application to the solution of his problems that, if he has at the same time this practical instruction in the use of the vehicle in which his reasoning is to be expressed when he wants to present it to those not trained in his own profession, he need spend but little time upon the subject bearing the label. If he does not have this training in English, he is a good engineer, but he may not be able to convince the average business man of this fact. So, from the point of view of practical use, as well as of effect upon the general training of the man and the engineer, this modern method of teaching English in engineering schools is to be commended.

I cannot forbear adding a warning note that it is quite possible to make the work conform too closely to the practical side and thus lose some of the real value of English as a study for engineers. This is more likely to be the case in institutions where there is not close co-operation between the English and the engineering departments and the engineers are relegated to classes in which the culture value is minimized. In such cases, also, the lack of knowledge of the conditions the engineer must meet are likely to reduce the value of the practical work and thus nullify to a great extent the efforts of the professors in the engineering departments to meet the needs of their students. I am glad to see that this criticism does not apply to Tufts College or to Kansas University. It is an evidence of progress when it is recognized that a man can not write intelligently upon a subject concerning which he is totally ignorant. Too much of the English writing in the schools, from the elementary grades up, misses this point and is consequently inefficient.

I see little to change in the practical programs presented in the two papers, though there will undoubtedly be differences in practice among schools, and can only express again in brief what it has taken a good many words to say above, that we, who are in the practice of engineering and of its application to the betterment of moral and spiritual as well as physical conditions, welcome heartily these advancements in the teaching of English to engineers, because we can see the great benefits which will result. They seem the greater to us because we have been suffering from the lack in engineers generally of the ability to express themselves, and because we have seen the serious effects of this lack of English training upon engineers who might otherwise have taken higher rank among those engaged in the improvement of social and business conditions.

Professor Frank W. Chandler (by letter): Professor Raymond's article sets forth some of the aims and methods of the English department at the University of Kansas in dealing with students of technology. Among the interesting practical suggestions of this article I find four. These are: (1) The endeavor on the part of the English department to coöperate with all other departments that require written work, (2) its endeavor to encourage all who write, by giving them something to write about in which they are really concerned and by preserving worthy articles so composed, in a manuscript library in the rooms of the rhetoric department, (3) its endeavor to assist, in a semi-official way, all who desire to use books for a special purpose or to express their thoughts and emotions in any kind of composition; and (4) its hope for a code of authoritative forms "to govern the use of special terms, abbreviations, capitalization, forms of manuscript, tables, bibliographies, illustrations, etc."

With regard to the last point, it may be said that such a concise array of rules as is given in Woolley's "Handbook of

Composition'' fairly answers this particular need, when supplemented by some study by the class of easily accessible sample specifications, contracts, and technical reports, and by the careful analysis of scientific articles from the best engineering journals. Since technical writing differs but little from any other kind of exposition, the student who has once gained the power of marshalling facts, inducing conclusions, and presenting his results with clearness and force, can readily learn from the reading of standard scientific literature any tricks of his special trade.

With regard to Professor Raymond's suggestion that the English department offer its services freely ''as an editorial council'' to the students to assist them in spilling ink, whether in writing college songs or in preparing public speeches and technical reports, it may be said that this should be part of the function of the English department in every school and college. Yet it is a function especially to be insisted upon in the school of engineering. There the student is likely to feel less inclination to write than is his collegiate fellow, and there, it is the more important for the English department to catch his interest and sympathy outside the regular class-room. Not many may voluntarily seek aid from the English department, but all should be encouraged to do so. Unless instructors are glad thus to give themselves freely to the students out of hours set down in the catalogue, they are clearly remiss in their duty.

Concerning Professor Raymond's suggestion that the student be made to write out of his own experience, so far as possible, that too is a requirement desirable in every composition course. But one great difficulty with students of technology is the fact that in their earlier years they feel their lack of sufficient technical knowledge to serve as a basis for writing. Moreover, many such students prefer to attempt the discussion of matters of more general interest, such as social, political, or even literary topics. I would by no means confine the student of engineering to the preparation of technical reports or the recording of laboratory experiments. Very little practice in the effective use of English is afforded by cataloguing formulas or enumerating the steps in a process. Clearness and force are the qualities of style in demand in technical writing, and exposition and argumentation are the forms of discourse most likely to be employed. But practice in such forms and in striving to secure these qualities may be had in any field, and it is certain that discussions of public affairs and of other matters of contemporary interest afford rich opportunities for the writing of simple and effective prose. If the student can succeed in dealing clearly and forcibly with such subjects, he will have no difficulty with the less inspiring and much easier business of writing reports upon laboratory experiments, explanations of formulas, figures, or scientific principles, descriptions of machines, and specifications for engineering undertakings. It is never to be forgotten, too, that the engineer requires a mastery of English less for use in appealing to purely technical readers than as an instrument to be employed in dealing with men in general in the larger relations of life. Most courses in purely technical English fail to take account of this fact.

The suggestion of Professor Raymond that worthy articles composed by the students be preserved in a manuscript library in the rooms of the rhetoric department is admirable. Such a collection of the best student themes sets a standard for the less skilled, and serves as an incentive to all for the preparation of careful work. But in order that the most should be made of any collection of the kind, the articles composing it should be typewritten. At present the teacher of English can merely look forward with longing to that millennial day when the use of the typewriter will be so common that all student themes may be required in this form.

As for Professor Raymond's suggestion that the English department ought to co-operate with all other departments requiring written work, that is the dream of teachers of English in every school and college. But how shall this co-operation be effected? It entails a great amount of work by the English department in supervising the papers prepared for other departments, and it entails also upon these other departments a responsibility which too often they shirk. It is seldom, indeed, that instructors in physics or mechanical engineering are willing to give a low rating, much less to rate at a failure, those who despite their technical knowledge are defective in English. But until the engineering student perceives that his professors in pure and applied science regard lapses in his English with the same disfavor as does his professor of English, he will not be likely to amend. What is needed is a practical scheme of co-operation whereby every written paper submitted to the departments of science shall be checked both for matter and for expression. In the first two years of the course, all papers in any of the science classes should be carefully examined on both points by the two departments concerned. In later years of the course the English department need take cognizance only of papers marked deficient in expression by the science departments and referred for further consideration to the specialists in English. In the Engineering School of the University of Cincinnati such co-operation is encouraged. Mr. Clyde W. Park, who is in charge of our English instruction for engineers, in a report just presented to the dean of the engineering school, makes the following statement, which the dean approved:

"Co-operation with other teachers who require written work is unquestionably one of the most practical and economical schemes for composition teaching. The success of our experiments thus far and the friendly attitude of the engineering faculty towards English, have emboldened me to propose a wider application of the co-operative plan. I should like to see the mark in English composition made a provisional one, to be withdrawn or changed to a condition on the complaint of any instructor who found written work that was below standard. Such complaint might even be based on the student's graduation thesis, though as a rule previous warnings and drill would provide against this calamity. If the student could thus be made to feel that his English was to be used in all of his courses all the time, he would form lasting habits of careful expression. Then his composition work would mean something more than a lucid interval in his college course, when he wrote respectable English long enough to earn a passing mark in a required subject.

"The enforcement of such a provision would not place so great a burden on the teachers of other subjects as may at first appear. Surely no one can read a manuscript without gaining incidentally an impression of the writer's skill or awkwardness in composition. If the composition is logical in arrangement and clear in expression, these qualities will be plainly apparent. If it is scrappy, general, or in any way unintelligible, the fact will be all too evident. To refer the faulty manuscript and its writer to the teacher of English, or to refuse to accept it until re-written, would be a simple matter. Moreover, since bad writing nearly always indicates lazy or muddled thinking, instructors in the various subjects have a common interest in the student's rhetorical welfare.''

So much for the practical suggestions of Professor Raymond's article. One remark that he offers upon the theory involved in teaching composition I should like to emphasize. It is this, that skill in writing can not be taught all at once, but grows gradually along with the student's general increase in knowledge and the refinement of his judgment. In short, poor workmanship in writing is but part and parcel of poor workmanship—carelessness, inattention—in everything. As the student learns accuracy, comes to discipline his senses and judgment in other fields of work, he will, if properly assisted, improve in his English. Carelessness and incoherence in expression is directly related to carelessness and incoherence in thinking and in handiwork.

Excellent, however, as are all these suggestions, I would enter a plea for something more in the English course of the technical school than Professor Raymond specifies. This is some study of literature in connection with the study of writing. Many of our schools of engineering already afford such courses, but let me, in closing this discussion, meet the contentions of those who still deny the utility of courses in literature for students of technology. Four reasons may be assigned for requiring the study of literature in the high grade technical school.

In the first place, the study of the works of great writers is indispensable to the man who would himself learn to write. No matter how humble may be the field for the exercise of his own skill in composition, the student's powers of expression will be best developed through the attentive reading of good literature. The proper meaning and value of words and the full significance of the qualities of style can be learned in this way alone. To quote from a recent article by Mr. Walter H. Page, editor of the *World's Work,* "Of the great literature itself no writer who wishes to do his best can be ignorant. He must steep himself in it. He must continue to live in it; for no man can write his best who does not read great writers constantly." This opinion has been affirmed also by such writers as Stevenson, Ruskin, and Franklin.

In the second place, no one who fails to have been brought into touch with something of the best in literature can hope to meet cultured men upon terms of ease and equality. As a matter merely of pride and of business, to seek no higher motive, it is necessary that the engineer should share with educated people everywhere a general knowledge and appreciation of the best in literature.

In the third place, apart from the practical considerations of the influence of literary study upon the writer and upon the man in society and in business, the student needs to be taught the appreciation of literature as opening to him new avenues of thought and enjoyment. He whose interests are bounded simply by the interests of his profession lives the narrowest and most resourceless of lives. Opportunities for relaxation, for recreation, and for inspiration are offered most freely by literature. This is the form of art, moreover, that is best adapted to convey ideas, and since it has been the chosen vehicle of thought for many of the world's most potent thinkers, whoever would feel the influence of their thought must be, to some extent, a student of literature.

Finally, and most important of all to the future engineer, the study of literature means the study of men. In such literary forms as the epic, the drama, and prose fiction, great types of human character are displayed in all their variety by those whose experience of life has been the richest. These types of character are exhibited, not statically, but in action: their emotions, their motives, their morals, their conceptions of life are not merely analyzed and discussed, but are made vividly real. The student of literature witnesses as in a laboratory an absorbingly interesting series of experiments with selected specimens of human nature. He learns to observe accurately differences in temperament, the play of ruling passions, the workings of conscience, the clash of character upon character. For him the minds and hearts of these personages are laid bare. At the same time he remains no mere spectator of the human show, but for the moment becomes an eager participant in it. Thus he learns inductively to know the laws that govern human life—a matter of even greater practical importance than a knowledge of the laws that govern things. No amount of abstract teaching of psychology and ethics, of biography and history, can take the place filled by this concrete presentation through literature of types of character in action. It is in developing the student's knowledge of men, in enabling him to select and to deal with men, that a study of literature should prove of inestimable service to the future engineer.

TEACHING OF SCIENTIFIC SHOP MANAGEMENT, WITH USE OF ENGINEERING SCHOOL SHOPS AS THE LABORATORY.

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In November, 1909, a "brief" on the desirability of teaching the new science of shop management, based on efficiency engineering, with use of the shops of the School of Engineering as the laboratory, was discussed with the president of the University of Missouri. In the next catalog of the University, printed in April, 1910, appeared in substance the following announcement of the new course to begin in September, 1910.

"*Engineering Shopwork.* Efficiency and Production Management. A shop laboratory course in functional foremanship or staff organization. The planning department. Class observations in elementary scientific time studies. Elimination of wasted time and needless effort. Despatching. Ideal conditions and standardized operations. Charting of production orders. Detailed order-of-work cards. Use of time and instruction cards. Studies of time and load factors. Finance calculations and tests leading to the selection or elimination of machine tools, with reference to the efficiency of the operator, earning capabilities of tool, and hourly overhead burden charges per tool. Tests of maximum economy in cutting speeds, shapes and steels. Tests of power requirements. Experiments on characteristics of general and specialized machines. Exhibits of highly developed machines by manufacturers' demonstrators."

There had been given for two years a course of lectures and reading, required for the M.E. degree, which is still being carried on parallel with the newer course. This is described in the catalog as follows:

"*Scientific Discipline.* A training in the principles of handling of men, as these are becoming well recognized, clearly defined, standardized, tabulated, accepted and used by successful, educated superintendents. The building up and preservation of an organization is more important than the material equipment of an engineering property. The selection and training of officers. Complaints, penalties and wage systems. The avoidance and handling of labor difficulties. Trades unionism. Methods, dangers and possibilities in the improvement of working conditions.''

The two courses make up the special training in *Scientific Shop Management.*

Lecture courses are not infrequent at American universities on the subject of factory management. The features which in the judgment of the joint authors give reason for this paper, are the careful analysis of the principles of scientific discipline, and more especially the use of the college shops as a laboratory in the teaching of scientific engineering shopwork.

Scientific Discipline.—As regards scientific discipline, colleges of engineering are becoming mindful of the strong note of incomplete satisfaction among many of those who receive the raw product of such colleges, voiced from Chicago by one who believes all colleges wholly bad, but hopefully voiced by a president of the American Society of Mechanical Engineers, a ''progressive'' in this society, whose paternity in efficiency engineering is without question. It is even alleged that the college-bred engineer is only fit to be ''used'' under direction by the officers higher up, with rare exceptions; and that no great mechanical enterprise owes its success to college men. It is possible that many of these at first unsuccessful young men have placed too great a reliance for future success upon a knowledge of the application of the laws of physical science, to the obscuration of the equal importance of a knowledge of the laws of mental science. This attitude is largely corrected by the teaching of scientific discipline or the handling of men in shops. The principles which lie at the foundation of control of subordinates lend themselves to analysis and logical arrangement. An understanding of these principles, enforced by suitable illustration, applied in numerous ways familiar to every educated superintendent, sends the young man at graduation into the shops prepared to learn the good and reject the bad methods of superior officers, and to act wisely when his own responsibilities come upon him for the first time.

Not everything can be taught in a university. Those subjects certainly can be taught which are open to the ''scientific method.'' A science is a systematic and orderly arrangement of special knowledge, an art is the actual performance of something; the art is doing, the science is knowing why and how. The salesman should better succeed in his art of selling if he can be conscious of being in harmony with the scientific principles governing his art. We know what the science of agriculture is doing for that basic industry of man. In a similar manner, economics is such an applied, practical science. In trade, the fundamental laws have always existed, though long unformulated. Men who traded in harmony with such principles won success. Those who violated these laws had failure thrust upon them in proportion to their violations. Nature is inflexible, and in business as in health and morality, ''ignorance of the law excuses no man.'' The penalty for violation is as great as though for wilful violation. There was a mass of facts, with true relationships concealed. Economics codified the natural laws of trade, makes clear their relations, and places in the grasp of men of affairs many of the secrets of success and failure. Such, also, is the result of teaching scientific discipline.

Engineering Shopwork.—As regards engineering shopwork, there has long been a feeling among engineering professors that college shops as commonly run were out of place in a scientific course. The deficiencies need not be enumerated here. The spread and excellence of manual training high schools, the coöperative shop courses, the requirement of two years of Arts and Science College work previous to entrance into the School of Engineering course (now in force in the University of Missouri) during which boys from non-manual high schools can have opportunity to make good any lack, have made it possible to introduce what may really be named ''engineering shopwork,'' shopwork in which there are real and serious mental problems waiting on solution. There can be no successful study without a problem to be solved, and therein lies the birth-history of the relation of laboratories to the "scientific method." It is true that there are problems outside laboratory courses, as well as the latter without problems, but the laboratory lends itself naturally to the presentation and solution of problems.

Furthermore, the developments of efficiency engineering, centering in the functions of the so-called planning departments or staffs, have furnished a new and very different subject matter as compared to what used to be called "Factory Management." The right management of a complex industrial organization is a science. Not unsystematized management nor systematized management, but scientific management will secure efficiency. Efficiency is the test of successful management. Efficiency is *not* a method of driving, with resulting physical and nervous hardship; but *is* a securing of far greater output, without any greater fatigue. In the old courses upon factory management, it did not seem feasible to use the common college shops as a laboratory. Such shops were not on a commercial scale of output, wages were not paid, the work of the students was not continuous, the product was not sold, there was no real competition, the primary object was instruction and not profit. But those same shops can to-day be used as a laboratory for the problems of the planning department. Students are being taught to solve the problems in the way they will use in the commercial shop after graduation. Engineering schools which have almost thought to dismantle their shops, can be happy to discover a most important use for them. Splendid as is the coöperative idea—and such shopwork gives a phase of education in man-understanding forever impossible in the college shop—yet until the cooperating shop has been "efficiency-ized," such shopwork will lack the training easily possible in college shops when conducted to teach the engineering shopwork of this paper.

The department of Mechanical Engineering of the University of Missouri has had one year of experience in teaching engineering shopwork. What is there to report to this Society? Of course the before-mentioned ideas were already known to any teacher who had given the matter thought. Before starting the new course, the authors of this paper made such a study of efficiency engineering and particularly of its application to the management of shops, as was possible for them. One went to a single instance of the installation of the new idea, under especially favorable conditions for getting an understanding of the situation. The plant was in the process of change, some departments having become fully efficiency-ized, and others not. The product was large and varied, a part of the officers sceptical, the efficiency engineer a mighty good fellow who took the professor quite to his heart. The visit was prolonged and invaluable. Later that same engineer came from New England out to Missouri at bare travelling expenses without consultation fee, after one semester of teaching problems had been met more or less satisfactorily, and staid with us one week, working almost day and night. It is proper that we should here publicly thank Mr. Miner Chipman, of the staff of Harrington Emerson. The other author spent a large part of last summer in visiting probably every shop which had introduced or was introducing efficiency engineering in the region included between Topeka, Chicago, Milwaukee, Cincinnati, Pittsburgh to Philadelphia. Also some shops in New York and New England. His more especial attention was given to shops running under Western conditions, if perchance there might be any differences, since the new course was to be given in the Mississippi Basin. As the one author gave somewhat more study to the Emerson methods, so the other author made a special visit upon Mr. F. W. Taylor, and it is also proper for us to give him our thanks. It is believed that a course of this sort can properly be introduced only by professors who have had a responsible shop experience following their actual work as ordinary mechanics, at some previous period in their history.

The course in scientific discipline has been regularly given to classes in full (the outline in this paper being but meager), for the same course has been given for several years.

The course in engineering shopwork was somewhat fully outlined in the catalog, since we wished to set a high mark which might or might not be reached the first years. The course was made elective the first year, in order not to have an unwieldy class, and that those who were to bear the brunt of pedagogical experiments might do so with eyes wide open. They worked loyally in developing the untried course, and in turn received full value in an understanding of the portion studied. We overheard them telling other students what ''good stuff'' those other students were missing by not having elected the course. They were always intensely interested.

The students in the course were upperclassmen, and the underclassmen in part were used as a laboratory. First a study was made of the available literature of the subject. This was parcelled out, read, reported upon and discussed. It was realized that the fundamental principles must be studied, and not mere top-heavy systems. Observance of this will make the wise man omit some books and chapters of books now on the market. After the public became interested in the Brandeis hearings the past winter before the Interstate Commerce Commission, the bulk of literature suddenly increased and bids fair to become enormous. A card index of all literature was formed by the class in September.

The class was organized into a staff, each student having a special function to perform. (That this was unwise is shown later.) The personnel contained the following officers: Mill Manager, from the Faculty, Chief of Staff, Engineer, Supt. of Standard Time, Asst. Supt. of Standard Time, Despatcher, Chief Draftsman, Cost Clerk.

Duties of Officers.—Chief of Staff. Keep a record of all meetings of classes, keep a line on all work the men are doing, see that they are doing all of their work, see that no one is infringing upon any one else's work, see that all reports are properly made out and filed, and act as a go-between for the Mill Manager and the Staff.

Engineer. Study the equipment, its efficiency, and condition, cost of power, management of shops, arrangement of machines and the installation of new machines, repairs, tools, etc.

Supt. of Standard Time. Make time studies, especially in the machine shop and the forge shop, establish standard time, assist in making shop cards.

Asst. Supt. of Standard Time. Assist Supt. of Standard Time, make time studies, especially in the wood and pattern shops, and in general the same duties as the Supt. of Standard Time.

Despatcher. See that the work goes through without any delay, make suggestions for time cards and drawings, give any spare time to time studies in the machine shop.

Chief Draftsman. See that all drawings necessary are made on time, are correct, and in the best form for the shop conditions.

Cost Clerk. See about the stock on hand, look after the cost of materials, tools and power, and devise a system for rewarding the men for their work that will be suited to the particular conditions of this shop.

All men are to assist in whatever work for which they can spare the time, make as many as possible of their reports in typewriting, all important work to be thus reported on the first Monday following the work, step by step, not waiting for the completion of the job.

The above was the first and most serious mistake. Students are untrained, and their available time is too brief. It is not possible for any one student to do a staff job with proper thoroughness. He will run behind. For example, it would take the entire time of an expert to "dispatch." Hence in college an elaborate system of dispatching is not feasible. Put the boys all together on "records" and again on "time studies." The mistake was not corrected until the beginning of the second semester. It is better to concentrate than to generalize. Where the class is divided into committees, appoint one man in each committee to be responsible for that committee to the Professor, and to see that each man in his committee understands and does what he should.

Staff meetings or planning department conferences were held weekly, at which progress reports were presented both verbally and in writing. When in writing, duplicates were given to all. The class made a study of each feature concerned in the work of the manual arts shops, such as tool-room methods, small tools, location of machines, improvement of machines, defective belting (a source of great loss), speed-meter work, methods of teachers, methods of students, etc. No subject was too sacred for investigation. In the real thing the very highest offices get investigated, the most serious faults being often found there. Turn a student loose, and trust him that he will find flaws in the way he or his underclass friends are being taught. Not all of his objections are justified, and he may not commonly know the best remedy needed, but happy is that college that is willing to invite the criticisms of its students while they are yet students. To quote from a thesis just read by the authors of this paper: "The University of Missouri, as far as I can ascertain, is the leader at present in the teaching of shop management and the handling of men or scientific discipline, but it will have to continue to improve to hold that place, as great plans are being made by other institutions, notably at Worcester Polytechnic Institute." The effect of the year's work has been good in every way. Students talk efficiency, professors talk efficiency, both have been stimulated, and this is true of those students and professors who have had no personal share in the course. The spirit of the Mechanical Department has not only not suffered, but it has never been finer.

In the above mentioned study, defects were remedied when time and money were available. During all of these preliminary studies, and those to follow, it must not be forgotten that the primary purpose of manual arts shops is educational. Changes are asked or declined as they may affect educational matters, the educational being paramount; changes which would be treated in contrary fashion were the shops commercial. This does not in any way vitiate the application of efficiency. In fact, the peculiar difficulties imposed for pedagogical reasons do actually make clearer the real efficiency principle; revealing the principle as a principle rather than as a hard and fast system. One of the serious errors into which the half-baked catcher-up of what he thinks is efficiency engineering falls (and we are not at this moment referring to college students), is his taking the shadow for the reality, the system for the principle, the method for the fundamental science. Therefore, instead of the pedagogical limitations being a hindrance, they are really an aid to good teaching of efficiency engineering by compelling the student mind to get out of the rut of the shop thinker. That is why the Emerson articles harp so seemingly interminably upon their everlasting illustrations drawn from trees, human bodies, the Franco-German war, the Nipponese, etc. He wants the reader to see the law, the principle, the general efficiency fact which can be applied in many different ways to industries as varied as steel making, boarding-house keeping and education. Every smallest situation met by an efficiency engineer in a plant is different from all other situations, and he must meet it with a clear knowledge of fundamental scientific principles, so that he may solve the individual difficulty in the peculiar, just-right way. That is why a lawyer of our acquaintance has become so good an efficiency engineer; his previous training had accustomed him to look at every side of a case, impartially, coldly, painstakingly, alert for the weak spot, when found—hot with the quick iron. Your rule-of-thumb, half-baked efficiency (?) engineer (God save the mark) goes and applies a ''system,'' makes a costly botch of his job, maybe the labor union gets justly roiled at his ''driving,'' and the owner or employee or both tell the public that efficiency engineering is guesswork, a farce and a failure. The trouble is, that the pet system was ill-chosen because blindly chosen. Not system, but principles, not methods, but principles, are needed. Scientific management is not a natural outgrowth of systems or even of system. It is not an evolution. It is rather a *reversion to type.* A great industry under scientific management closely resembles in its essentials the small shop, in which the owner and his few men intimately connected with him were studying and working intelligently and harmoniously with a view to perfecting the operation. In solving the problems of inefficiency in the large shop, the greater burden should rest upon the management and the smaller upon the men. The unscientific large shop has a manager most distantly removed from a vital connection with the operation, and the latter is left to those unable to give it intelligent study. The performance thus becomes the concern of the less intelligent help. The management performed its function when the order went from the office to the shop, and was then free from further concern until the job was completed. Introduction of system has helped some, by following the order and checking it at various stages of the work. The highest development of system, however, has been found to lead, not towards the essentials and a solution of the problem but away from them. Therefore a new start has had to be made in the large shop—a reversion to the small shop type by a discovery and study of fundamental scientific principles. A college is just the place to start young men into right ideas of principles, in the atmosphere of impartiality and investigation.

The class prepared to engage in elementary time and motion studies in machine, forge, and wood shops. For example a simple job of making a pattern was chosen. The work was subdivided into operations. Drawings were made, with each important step shown. A list of all operations was also made out. After a report and conference in the planning department, blue prints of these drawings and lists were issued to the freshmen as detailed order-of-work cards. In a college shop, too much detailing of instructions must be avoided. The freshman must be allowed some initiative and choice of methods, for his own good. Also, for the senior's good, there must be by him a study of all the freshmen in his group, in order that he may learn from them still more of what are the best methods. Then watches were held upon the freshmen and the time taken for each elementary operation. These time studies showed that some of the elements were not sufficiently subdivided for best time and motion study. In actual efficiency engineering practice, it is sometimes a study of months, to determine elements, before beginning the time study. The senior may need to ask the shop instructor's help and advice. More time studies were taken, results discussed, lost time pointed out. Improvements were made, tending towards ideal conditions. Each machine, for instance, had all necessary tools placed in a tray in the tool room, and the tray issued thence to the workman. The blue print was fastened to a stand convenient to the man's eyes when at work.

This analytical study of minute elements, with the improvements, was followed by synthesis. Out of the synthesis was evolved the science and art of making the article. This science and art take the place of insufficient knowledge and rule-of-thumb method, and *it must be evolved by the management itself,* not by the workman. Scientific management rests upon a definite and sufficient knowledge of everything connected with the manufacturing of a line of goods, and has as its aim efficient production. As in the old, small shop, the brains are now concentrated on the actual making of the article.

''Standard time'' for this perfected job of pattern making was discussed by the class, and decided upon. Time cards of the freshmen were assorted, and compared with the standard time. The percentage of efficiency was figured, and a paper-bonus awarded to each of the freshmen earning it. In the college shops, it is probably not wise to tell the shop men what efficiency or bonus the time study on them shows. The work is done for the good of the seniors, and when that good is attained, stop.

Despatching was instituted. A despatch board built. Service cards planned, compared, discussed, adopted. A student would be given two wood lathes and seven wood-working benches to despatch. Without interfering with the instructor, it was ''up to'' him to keep his freshmen supplied with work, and these two machines busy earning their keep. He was told that he must work without interfering with the education of those freshmen in any way, he must not tell them what to do or what not to do, or how to do anything, therein being in a predicament similar to the efficiency engineer who is required to institute reforms without killing output. If the senior bothers the class or the instructor, put him out or make him practice time-study on street or university farm laborers; until he comprehends that tact is part of his function. If a shop instructor was found who rather looked askance at what he feared was to be an interfering with his teaching, the situation was welcomed rather than otherwise; it compelled the senior to exercise more tact, and he had to do his work and make the instructor like to have him around. Some one in this audience will call that an unconquerable optimism, a great strain on the senior, a coming up smiling no matter how many underhanded, mean and dirty kicks he gets. That's right! And that is just what a full-grown efficiency engineer has to do. If a man is looking for a nice, easy time of smooth sailing as an efficiency engineer, because he thinks he has the owner on his side, that man is a good one hundred per cent. fool. He must "get solid" with all the unprogressive foremen in the plant, and simply make them like him and believe in his methods. The senior is fortunate if he can have a taste of that sort of thing.

In some of the work, seniors study the work of each other, and sometimes the work of an expert instructor. Competitions were carried on, and the reasons for success and failure were discussed. Street laborers and other workers were informally time-studied by students in off hours. Station stops on the Wabash Railroad were similarly time studied. It was evident that late trains did not need to be so late, or even late at all in some instances. A study was made of the culinary department at the big University dining hall, a report made to the rest of the class and to the manager of the dining hall.

A side light on using the opportunity was afforded in the semester just ended when our shops were destroyed by fire. Thirty-six hours later, the efficiency class was busy planning temporary shops and equipment, which were installed in record time. It was at this period that the University dining hall was studied.

During the year, a highly specialized machine was brought to the University, and the makers sent an expert demonstrator to operate it. This was used to turn out a very great amount of product, showing such a machine's commercial possibilities. This summer, after correspondence and by invitation of the makers, one of the authors is to spend several days at the makers' works, and show them what is wanted by us next year in their various demonstrations before our students and in our time studies in connection therewith.

Should objection be made that in college there is no method of reward for individual increased efficiency, it ought to be remembered that of the twelve Emerson "principles of efficiency," only the last one is a reward. An efficiency engineer can make tremendous savings by the other eleven. Some efficiency engineers advocate omitting the reward, in cases where at first they may find intense union opposition to the new ideas, or for other sufficient reasons. It is, however, possible to have rewards in college for those who attain greater efficiency. These rewards may be: to let the student out early, to give him advanced work, give him work he desires, higher grades, additional hours towards graduation, money from the manufacture of small duplicate parts for local factories or others near by.

As fast as improved pedagogical methods are found to conserve the students' time, additional items in engineering shopwork will be introduced. Perhaps half of the class will follow the strict Taylor system, the other half the strict Emerson system; or a third group may select from both systems, following neither exactly. Graphs will be made of improvements of men in the machine shop, as they get more familiarity with machine work. The "exception" system of reports will be employed. Studies in fatigue will be carried on, for efficiency engineering must not cause undue fatigue. The department of experimental psychology has become interested, and methods are already in mind for the expert selection of temperaments and physique for certain sorts of shopwork, instead of the existing "judgment" of employer or foreman, or the long process of cut and try. One of the professors of economics has become intensely interested, and we expect good help from him, and the help will be reciprocal. The President promises to fit up a special shop laboratory for the use of some of the efficiency courses. The superintendent of a large local factory is getting interested, and there promises to be a good laboratory opportunity there. Building and paving operations in town and University afford an extensive field, since the city has doubled and the University trebled in this decade.

It is probable that courses will soon be developed especially adapted for teaching civil engineering students, electrical engineers and chemical engineers. We are thinking of putting the mechanical laboratory and the mechanical drafting rooms on an efficiency basis, making the usual preliminary studies, of course. In fact this year a class in drafting room management, made up of students not in the course in Engineering Shopwork, has outlined the methods for doing this.

Being a state university, we plan later to invite the owners of industries, including the railroads, to detail certain of their officers to come to the university free of charge and take studies in Scientific Management. Woodworking has apparently not been studied after the manner of Taylor's "Art of Cutting Metals." It is a cheap material to buy and work, machines and tools are inexpensive, colleges seldom have any superfluity of money, and for the sake of the students a line of research may be entered upon in this subject.

A state university, with its intimate relations to the state, is under special obligations to serve its state. A number of good things along efficiency lines suggest themselves for this service, many of them entirely outside of shopwork. Our comparatively young Engineering Experiment Station may profitably take up some of this work, and thus still further justify its existence by an added service to Missouri, or rather, to all of its inhabitants. A state, especially if largely agricultural, needs extensive, diversified manufacturing industries if it would be well balanced, most prosperous and progressive.

A state university should promote its state's growth and efficiency in this direction.

There is incentive for thought and action in this extract from Frank B. Gilbreth's new book on Motion Study:

> "There is no waste of any kind in the world that equals the waste from needless, ill-directed, and ineffective motions. . . . Tremendous savings are possible in the work of everybody—they are not for one class, they are for the trades only; they are for the officers, the schools, the colleges, the stores, the households, and the farms. . . . It is obvious that these improvements must and will come in time. But there is inestimable loss in every hour of delay. The waste of energy of the workers in the industries today is pitiful. . . . In the meantime, while we are waiting for the politicians and educators to realize the importance of this subject and to create the bureaus and societies to undertake and complete the work, we need not be idle. There is work in abundance to be done. Motion study must be applied to all the industries. Our trade schools and engineering colleges can:
>
> 1. Observe the best work of the best workers.
> 2. Photograph the methods used.
> 3. Record the methods used.
> 4. Record outputs.
> 5. Record costs.
> 6. Deduce laws.
> 7. Establish laboratories 'for trying out laws.'
> 8. Embody laws in instructions.
> 9. Publish bulletins.
> 10. Coöperate to spread results and to train the rising generation."

Such, from one qualified to speak by years of expert experience. And yet his words refer to but one phase of the subject of scientific management.

Visits to Columbia began during the semester just ended, for the purpose of investigating what has been attempted. A most cordial invitation is extended to anyone for this purpose at any time during the coming year, when all seniors in mechanical engineering at the University of Missouri will be required to take the courses in engineering shopwork and scientific discipline.

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And many papers in the *Transactions of the American Society of Mechanical Engineers.*

DISCUSSION.

President Talbot: Efficiency seems to be the watchword of the day. This is a very interesting and valuable paper and it is now open for discussion.

Professor E. J. Kunze: I am thoroughly in accord with Professor Hibbard's ideas on the training of the efficiency engineer. Handling men is one of the important things that the engineer has to do. It is quite as important as handling things. The engineering student should, therefore, be taught to handle men as well as materials. During the past year such a course has been introduced in the Michigan Agricultural College. It is correlated very closely with the machine design and shop courses. For instance, in the case of jigs; the jigs designed in the drafting room were afterwards made up in the shop by students and we expect to use the jigs in the manufacture of certain parts of our equipment. The work in office management was also taken up, and such matters as standardizing conditions in the drafting room and other parts of a work, forge shop and foundry, etc., were considered. We use a standard system in the drafting room, standard pattern numbering and a standard pattern storing system.

As Lansing has a great many automobile factories it lends itself very well to inspection purposes. We make a great deal of specialized inspection trips. We inspect, for instance, turret lathe methods and other allied matters on a given afternoon, or we might concentrate attention on jigs, depending on the subject matter which is being taken up at the time.

There is another feature that we expect to introduce to give the students an idea of the amount of time that should be taken to finish a piece. We shall put on a blueprint the time that a regular mechanic, with the equipment available to the student, would require to complete the operation or to finish the piece of work. Attention will also be called to the cost of that time and of the equipment used and the comparative cost of making that same piece under improved conditions in which a special machine tool, jig, or automatic machine is used. Our object is not to press the student unduly. He is allowed time to do a good job, but he knows while he is doing it that it ought to be done in a certain shorter time. He knows his rate and the rate at which he ought to work. Thus he is studying production while he is producing.

I believe that it is possible to teach a certain amount of foremanship to students. One of the best examples of that is at Pratt Institute, where they have a foremanship system in which students are allotted work of supervision in the shop as well as in the laboratory and drawing room. By that means they become familiar with the handling of men.

Mr. Kent: There are a good many sides to this question, one of which was exemplified recently. An alumnus of a certain large technical college in this country wrote the president asking if it would not be a good thing to introduce a course of lectures on scientific management. The president replied, ''If we introduce all the things we are asked to introduce there would not be any time for study,'' and declined to do anything whatever. The reason for this reply is that the president is a man so full of ideas himself that he has no room for any new ones. He is like a flywheel at high speed, charged with energy but with no chance to take on any more. This idea of scientific management is being thrown off tangentially by perhaps the majority of men in this country, because they have not been educated up to it.

I consider the new departure in using the shop of the college as a laboratory for scientific management a good beginning. I do not know whether it will succeed or not, but if Professor Hibbard has a new idea and has a chance to try it out, he should certainly do so. I hope that two or three years hence he will bring in another paper showing how the plan works and what modifications he has had to make. This question of laboratory practice in scientific engineering is now about where manual training was thirty years ago when, in the manual training schools in St. Louis, Professor Woodward showed me boys hammering sheet lead into shape before they began with hot iron, a kindergarten method. But that very kindergarten method has revolutionized many of our ideas. So it may be with teaching engineering in the college workshop; it is a kindergarten method. It has about the same relation to actual efficiency in the shop that the manual training teaching of a boy with the hand saw has to the modern sawmill with all its modern machinery. But I believe it is a good thing to go as far as you can, even in a small experimental way. If you pass the boy through a college course, with the ordinary training and without saying anything about efficiency, he goes out entirely ignorant of an important part of the engineer's life.

It is only forty years since the first mechanical engineering college was started in this country. This idea of efficiency in engineering is today where mechanical engineering was, in the schools, forty years ago. Very few people in the country then believed it was possible to teach mechanical engineering in the schools. Such teaching now is universal. So we may teach efficiency in engineering in the schools, although the beginnings are so small.

There is a gradual broadening out in the idea of what engineering is. It has been said that engineering is the science and art of directing the great sources of power in nature for the benefit of man, the sources of power referred to being wind, water stored at an elevation, the energy stored in fuel, and the muscular power of animals. And the fundamental studies necessary for engineering under the old idea were English, mathematics, drawing, physics and chemistry. To these fundamental subjects we now have to add two more: economics—what you can do with a dollar—and human nature —what you can do with men. And those things are as necessary parts of the work of the engineer today as mathematics, because the engineer today is not merely the man in the drawing room. He designs things, but he is the captain of industry, the man who has charge of the whole business. Now engineering has a new definition—overcoming the resistances of nature, including human nature. The engineer today is in charge of the productive industries of the world; and our engineering industry is evolving those two elements, economics and knowledge of human nature. I am glad that Professor Hibbard is a pioneer in teaching one of these things, the study of human nature.

Professor A. L. Williston: Professor Hibbard has called our attention to a matter of great importance. He uses the phrase, ''those institutions that are considering dismantling their shops.'' That phrase calls to mind the fact that there has been a tendency during the last ten or fifteen years to attach less and less importance to the shop work in colleges of engineering. Our shops have been manned very largely by low-priced and inefficient men. The available money has been spent in other directions. There has been a tendency to crowd the shop work into the early years of the course instead of saving a place for it during the later years. There has been a tendency in other places to crowd it into the summer and to decrease the time, interest and attention given to this very important and essential part of the training for modern engineering. There is, however, at least one institution that has really gotten the ablest and best men of the institution thoroughly interested in studying the possibilities of the shops as a means of training engineers. I do not want to endorse in detail the ideas presented in the paper or the ways in which they have been worked out during the current year, but I do endorse most heartily the principle of getting the best men in the institution at work on the problem of determining how shops can be made most useful in training mechanical and industrial engineers.

During the past ten or fifteen years, while a decreasing amount of attention has been given to actual shop practice, there has been a tendency to increase the number of lecture courses on shop management and similar topics. In these courses persons talk to students about processes instead of giving them an opportunity either to obtain practice by doing them or to see the processes carried on under real working conditions. We have gone too far in many instances in our courses in giving students instruction that is intended primarily to impart knowledge, and giving them too little time to acquire habits similar to those which they are going to use in after life. I, therefore, appreciate this paper calling our attention in a forcible way to an experiment pending in an opposite direction.

Professor Hibbard: Professor Kunze said that in his plan the time in which a certain job should be done is told to the student. That is a wrong principle from the point of view of using the shop as a laboratory. The student of scientific management should himself make the time studies and thus find out how long it should take to do the work. The idea of this paper is that the shop is to be used as a laboratory, and in the laboratory students find out things for themselves. We want to show them how to find out for themselves. Professor Kunze also stated that some of the work was done with specialized machines and that the student was then told that this determines the speed at which the work would be done commercially. It is one of the vital principles of scientific shop management, in the manufacturing company where I spent some time last summer, that the gain is not necessarily obtained by throwing away old machines and using new specialized machines, but by making the most of existing equipment.

Mr. Kent said, "I don't know whether or not this shop laboratory will work." In reply I would say that it is actually working. He said, "It has about the same relation to real efficiency engineering as the school shop to the actual shop." I do not agree with that at all. Here are four principles that Taylor splendidly abbreviates, the fundamentals of scientific shop management indeed:

1. Determine accurately by scientific analysis the elements of each job of work and decide how it can best be done.

2. Select men who are fitted for the work—even for the lowest kinds, and train them in the way that has been determined to be the best way of doing that task.

3. Provide adequate supervision and a system of payment which gives the men an incentive. Make sure that the men practice the best methods all the time.

4. Divide the work between the management and the men so that the management does all the work that it can do better than the men.

There are several suggestions here that we are making use of in our shop laboratories. We claim that the use of the shop as a laboratory, with the teaching of scientific shop management, is not like the school shop as compared to the real shop, nor like manual training compared to the real thing in the real shop. The principles and the methods taught the student, are the same which he will use after he graduates into the real commercial shop.

Professor A. J. Wood: I simply want to state that at the Pennsylvania State College there is a four-year course in industrial engineering, and there are about thirty students taking that course. It is not regarded as an experiment but rather as essential in the college training as many of the other courses. It has awakened a good deal of interest among the manufacturers of the state as shown by the many inquiries received relative to this special training. Furthermore, the time and motion study system has been put into actual operation among the students, the same as in the prescribed systems of scientific management.

Professor Kunze: In what I said before, I did not mean to imply that all the work is done by means of jigs and very fine instruments. We have some jigs, and as the men have seldom seen jigs before coming to college, they should become familiar with these devices. Modern manufacturing shops use jigs to a very large extent. Further I did not mean to imply that we abolished time study by the students. The time study will be done by the men who are last in the machine shops, but for the men who are working on details, it seems to me a given amount of time ought to be allowed for each part. We cannot estimate the time to be allowed for each piece made in the machine shops, because we have cut down the number of exercise pieces to a minimum preferring to make pieces which become parts of machines for our own equipment, for sale or other purpose. It is only in the case of the exercise pieces that an amount of time can be allotted, but on new parts, time study can be worked very well.

Mr. A. Stucki (by letter) : I agree with the authors that efficiency must win out finally even without having the schools to teach it, but the valuable time, money and energy lost by this slow method is inexcusable. I was connected with shops where the output was increased 25 per cent. by simply putting all the detail shops on a daily schedule with a storing privilege for one week. In this way the output was never hampered in erecting these details, and what is equally important, the machines didn't have to be changed from one job to the other as often, thus saving money and improving the workmanship as well.

Again I have seen the quality of work improved and the expense of discarding poor work reduced to a minimum, simply by systematic identification of each piece of work entering into the whole structure. In another shop, where great numbers of similar pieces are manufactured, watching the men and its adherent worries have been greatly done away with by simply keeping each man's daily work separate, and when night approached his "pile" would at a glance disclose the output, and the standard of the workmanship could be kept up at the risk of the man. I fully agree with the sense of the paper that efficiency is not a method of driving; on the contrary we must have the good will of the man in order to get his best effort, and strict impartiality goes a long way in this direction.

To come back to the problem of teaching economy as outlined in the paper, the "Scientific Discipline" has been very nicely outlined and this end is comparatively easily conquered by simply studying human nature and applying the proper ways in each individual case. But to work out a system and to teach a system which would be applicable to the millions of different kind of shops would be an utter impossibility, since only one shop, *i. e.*, the engineering school shop is available. This in itself would be a sufficient reason to teach the underlying principles, rather than a system. In fact, this is the only rational, effective and comprehensive way to master any large field of study and it is comparatively easy to apply the principle in each individual case as they may appear in life. Possibly this fact explains better than anything else, why it was found necessary to put the boys all together on a certain study at a certain time instead of specializing. I, of course, agree that only professors with responsible shop experience should undertake this branch of teaching. I do not think, however, that it is necessary or even proper, to apply a so-called efficiency system to a drawing room. Here a judgment of a higher nature is required to obtain the best results. I know several large firms which go entirely too far in making a mechanical establishment out of their drawing room, and what is gained in one place is doubly lost in another.

The paper states that the freshman must be allowed some initiative. This I consider absolutely necessary and also in the industrial shops it should be encouraged to a certain extent. This is the only way to progress.

An efficiency engineer is in a similar position as an inspector, if he does his work conscientiously he gets mifted from below and often ignored from above, and the author's advice to ''get solid'' is certainly in order. It is self understood that new reforms should not affect the output adversely, barring exceptional cases, where in order to reduce the first cost, temporary sacrifices had to be made.

Speaking of the paper as a whole, I consider it a most valuable contribution in the solution of this most important question and the thoroughness with which every phase has been considered and solved is proof that the authors themselves have had a good deal of actual experience in this line. My respective experience has emanated in railway shops, steel car shops, foundries and specialty manufacturing plants, and what I came across there is in principle covered in the paper, and specifically in regard to making use of the school shops in a double capacity I must most heartily congratulate the authors and the school both.

Mr. C. J. Morrison (by letter): I have gone very carefully through the paper on scientific management and am able to suggest very little. It has gone into the matter quite thoroughly and I can see no reason why this college course should not be a great success. In looking over the staff appointments, I notice that there is no one responsible for standard conditions. It is of the utmost importance to have some one definitely responsible for establishing and maintaining standard conditions. There is only one best way of doing any job. This way should be determined, made standard, and the standard maintained.

A dispatcher should not only see that the work goes through without delay, but should see that it goes through in its proper sequence of operations, and also that all parts, not only go through without delay but arrive on the erecting floor or in the store house at the proper time. He should also foresee every want of the workmen and should see to it that the workmen have proper tools, hoists, jigs, etc., in advance of each job.

The ideas as to a cost clerk are slightly different from ours, but, accepting the ideas as given, would suggest that the cost clerk go farther than see about ''stock on hand.'' He should provide a running inventory, which would not only show stock on hand at all times but would also show maximum and minimum to be carried.

Like every other practical application of scientific principles, scientific discipline demands a knowledge of general principles, and a conception of the conditions under which such principles are to be applied. Principles are reasonably fixed, but conditions are wholly variable and mutable. Hence it follows that the successful scientific manager must be one who has ability to see and grasp every situation in such a manner that he can determine the separate features, the relation of each feature to the other and the complete whole. This must all be done with direct reference to the results sought to be obtained under the conditions which cannot be changed. In other words, while the ideally perfect system of management is to be sought after, the unchangeable and specific conditions must be recognized and only such changes adopted as may result in ultimate gain.

Principles may be and should be taught in the schools, but judgment in the application of principles can be acquired only through experience. Experience is needed to distinguish the relative importance of details of efficiency, which relative values will differ according to the conditions controlling each specific case. Experience is likewise essential in order that one may know how to handle conditions which it may be possible and desirable to change. The knowledge of economic laws is necessary in attempting to deal with the ''labor problem'' anywhere, but no amount of such knowledge would enable anyone to handle a specific phase of this problem unless he knew how to handle men, and that is gained only through practical contact.

Mr. H. A. Gillis (by letter) : Whatever is done by our colleges in the way of educating young men to become efficient managers should be by making clear the principles of right thinking and correct analysis. The great value of Emerson's papers on scientific management is the fact that they do not attempt to teach hard and fast details of management so much as to start men thinking along the right lines, and the fact that the illustrations which Mr. Emerson uses in many cases are not taken from manufacturing work at all makes them all the more valuable.

The headings of the authors' scientific discipline course refer to the principles of handling men being clearly defined, standardized, tabulated, etc. It seems to me that only very general and particular principles can be recognized in the handling of men. Without attempting to classify these in order at all, I should set forth as some of the vital principles which are absolutely essential to the successful handling of men—impartiality, integrity, sympathy, respect for the better element of employees, harmony, or *pull together,* self control, decision, fearlessness, evenness of temper.

If these are what is meant by "principles of handling men," I agree with the writers. The teaching of these principles by examples taken from actual experience cannot help but the useful and helpful, although I think that all men who have had much experience in the handling of men will agree that the handling of men, or leadership, is a gift that is to a great extent natural or inherited. Nevertheless, the man who has natural ability as a leader will become still more able if he applies to his natural ability these fundamental principles. The great trouble with most of our scientific management systems is that they leave out the fundamental principle which was put into the heart of man by God Himself, that is, the principle of love. No man, in my opinion, is able or fit to handle men unless he possesses to a very large degree love for his fellowman and the natural charity and sympathy which flows from it. Once men are convinced that the manager possesses this characteristic, and are convinced of his sincerity and honesty, then he can introduce almost any system successfully. The keynote of success all the way through in any management is the faith of the workers in the leader. Some men are absolutely unfit for the handling of men and always will be, no matter how high their scientific achievement, while there are others who with proper training are capable of becoming able leaders.

A college course in discipline should embody so far as possible, a careful study and discussion of labor troubles; not only the general principles which produce labor troubles, but specific labor troubles—lectures by successful handlers of men, and proper instruction along the above general principles of management would, I think, be invaluable to the student in after life and create a demand for the graduates of any college that thoroughly trained young men along these lines.

The authors have covered the whole matter of engineering shop work quite tersely in the following:

> "It was realized that the fundamental principles must be studied, and not mere top-heavy systems. Observance of this will make the wise man omit some books and chapters of books now on the market."

I am thoroughly familiar with the various systems advocated by Messrs. Taylor, Gant, Emerson and others, and all of these systems have much of good in them, but they are only useful when intelligently applied, for a system that will apply to one class of manufacture would not apply at all to another, although the fundamental principles of the system might apply. So it would seem that what should be taught the student at college is not to imitate any of these systems, but to make intelligent application of their principles. There is in all of these systems too great a tendency to do away with self-reliance and initiative.

I note with much interest the statement that "scientific management rests upon a definite and sufficient knowledge of everything connected with the manufacturing of a line of goods and has as its aim, efficient production." This very statement demonstrates clearly the absolute necessity of co-operation of the management with the individual workman. Certainly this is true in a great many cases. Take the case cited of the lawyer who has become an excellent efficiency engineer. Accepting this statement as a fact (that this lawyer has become an excellent efficiency engineer), he certainly could not attain this success from his own knowledge alone. It has been due to his training in careful and exact analysis and his ability to win the confidence and the co-operation of those men who know the mechanical details and facts, for he must be dependent for many of his facts and premises on the information furnished him by the workers themselves.

Further, I note, in the author's reference to an extract from "Motion Study," by F. P. Gilbreth, that he makes use of these words: "And yet his words refer to *but one* phase of the subject of scientific management." Also, I specially note the bibliography on this subject, and the conclusion that I am bound to arrive at is that any college which attempts to go into too much detail in the instruction of students in scientific management will make a sad mistake, whereas the college which instructs them thoroughly in principles will do a useful work.

Mr. Fred H. Colvin (by letter): The words "scientific" and "efficiency" have been so misused in connection with shop management as to prejudice many against nearly all of the methods which claim them. There is no question however that the persistent work of Taylor, Emerson and others, have awakened a real interest in the improvement of shop methods. Many careful and thoroughly practical men, men who have been successful in managing real shops instead of studying the question from a purely academic standpoint, are avoiding the terms as much as possible and prefer to call it rational management.

If the warnings of my friend Professor Hibbard on page 92, against taking the shadow for the substance are heeded, such courses as he suggests and is evidently practicing cannot fail to do good. The great danger lies in regarding too seriously Mr. Taylor's statement that "In the past man has been first; in the future the system must be first." This should be contrasted with the saying of the great Disraeli: "We have placed too much faith in systems and too little in men." Can anyone with practical experience in the handling of men, doubt the latter is the more correct?

This blind (in too many cases) faith in a system and the erroneous idea that there is necessarily *one best way* of doing every job, are the two stumbling blocks against which the students should be carefully warned. Few object to any rational system of time study, and it is undoubtedly the basis for the elimination of many of the unintentional wastes which are all too common. But no system alone can tell what allowance should be made for unexpected delays due to hard castings, breakdowns, etc. The judgment of a practical man saves the day in all such cases. True, the hard castings should not exist and machines should be guarded against breakdowns, but here again judgment rather than system must do the work.

A planning department is an excellent institution if it works *with* the shop, instead of being on a pedestal, as in some cases. The danger lies in not having practical shop men in this department and in allowing the members to feel that they are next door to being infallible. This attitude arouses antagonism in the shop which counts against efficient production. Standard time, various piece rate plans, despatching, cost accounting, etc., should be carefully studied, bearing in mind that each plan has some good points and that none are free from possible abuse by both parties. There is no place where the ability of getting down to the plane of real humanity counts more than in the method of wage payment.

The course of scientific discipline opens great possibilities and also great dangers. If the idea of system is uppermost, it can be depended on to cause more dissension than any one thing I know of. If on the other hand the principles of Disraeli are followed and system made secondary, much good can be accomplished as there are too many instances where shop discipline is entirely dependent on the whim of a martinet, to the constant detriment of all concerned. But when all is said and done, it must be recognized that efficiency is always relative, that men would often be glad to work at an extra pressure on days when they feel particularly energetic if it were not for the fear—too well founded in many cases—that the maximum day's work will be considered as a standard, with no allowance for days of lowered vitality and that managers often require as much educating as the men. And no time study or planning department will ever know the maximum efficiency of a man or of a machine as long as there exists the possibility of a reduction in the time limit or the pay for the same amount of work. Some of the exponents of the different systems of management lay down a multitude of principles, which can be boiled down to two. And these two are older than we realize, going back to the beginning of manufacturing. They are: the division of labor and the use of accumulated data. The other so-called principles are built around them, and often tend to hide the vital points.

Nothing is further from my mind than destructive criticism. My only desire is to prevent any student from placing too much dependence on any iron-clad system in any work which involves the handling of men. For unless the variables of the human element receive due consideration he is sure to find trouble and disappointment sooner than he desires.

Dean C. H. Benjamin (by letter): I have read the paper on the teaching of scientific shop management with considerable care and have also submitted it to Professors Golden and Turner of the department of applied mechanics at Purdue, so that the discussion here presented represents the aggregate of opinions from those especially interested in the subject at this institution.

It does not seem that the system outlined in the paper would be practicable or successful here, partly on account of the large number of students handled and partly because their knowledge both of shop methods and of educational processes is so slight. There are but few manual training schools in this state which so teach men the elements of shop training that, on reaching the University, they can take advanced standing. Necessarily, much of the time of instruction in shop work is given to teaching the bare elements of mechanical processes, leaving but little time for study of different methods or for time study. All is done that can be done in the time allotted, by means of shop lectures and by a comparison of ordinary methods with advanced manufacturing processes. It accordingly follows that the same student, when he becomes a junior or a senior, is not qualified to pronounce on methods or to direct other students. Ordinarily, the student who has received shop instruction in the university would not be capable even of teaching elementary operations successfully, much less of conducting any advanced motion or time study. The average senior student has not the experience or the judgment which would justify his taking any part in the instruction of the underclassmen. There is a feeling that any such system here would result in anarchy.

We all appreciate the desirability of an application of the principles of industrial engineering in the university shops, but believe that this must be confined to lessons given by the instructors. The whole atmosphere and surroundings of a college shop are so different from those of the commercial establishment that a study of the conditions there might do a student more harm than good, giving him false estimates of the capability of men and of the commercial methods of doing work. A plan which has been presented and carried out to some extent is that of allowing senior and junior students to figure costs from the time and material cards of the shop. Even this is a difficult problem to handle with a large number of men, but it does not involve any interference of students in the administration of the shops. It is difficult enough now to run and administer college shops in such a way as not to give the student false standards and ideals. In our opinion, to complicate this problem still further by trying to get manufacturing economical data would be disastrous.

I am sorry to take a critical position in this matter and am open to conviction but I feel strongly that it is better not to teach a subject at all than to teach it in such a way as to give false standards and misleading impressions.

Professor W. D. Ennis (by letter): Various engineering schools, including Columbia, Stevens, Worcester, and the Massachusetts Institute, give courses of from 10 to 120 hours duration in what is variously described as "works management," "economics of engineering," "shop management," "industrial management," etc. At the Polytechnic Institute of Brooklyn, for four years we have been trying to teach works management, the course being a development from part of a much older course on "mill design and administration." The following is the description of the work as given in our current catalogue:

> "WORKS MANAGEMENT. The principles of business organization; classification of industries based on ratio of cost of plant to annual productive power; influence of form of organization on engineering practice; aim and method of cost keeping; the use of curves in statistics; depreciation; labor problems, piece work, premium and bonus systems, employer's liability, trades unionism; distribution of fixed charges; economy of administration; engineering specifications and contracts; patents and patent laws; the principles of accounting; corporation accounting; analysis of annual reports; apprenticeship; actual cost systems in foundry, forge-shop, and machine-shop; modern tendencies in administrative engineering; the place of the technical graduate in the industrial organization. Seniors in Mechanical and Electrical Engineering; one hour, second semester."

This outline has been revised every year and the subject will probably not be given next year in precisely the way described. Our upperclassmen take advanced work in economics and in the law of contracts which will make some of the scheduled discussions unnecessary. We shall probably omit entirely, the subject of patents on account of lack of time.

Aside from these modifications, there are two essential differences between our program and that described in the paper. First, the time we allow is only fifteen hours; second, the scope we attempt includes far more than what is commonly known as "shop management." These two distinctions, taken together, may impress some as reflecting unfavorably upon our good judgment. The reasons for our attitude may be briefly—if somewhat disconnectedly—summarized thus:

1. We think that management is as yet more of an art than a science, and it is our business for the most part to teach science—applied science. There is so much applied science of fundamental importance which the student must consider that even for this momentous subject we cannot, as yet, provide more time.

2. We do teach "shop management" in the narrower and more specific sense which is suggested by its synonym: *Taylorism.* "The Art of Cutting Metals" is used as a reference text in our shopwork. But we think, first, that Mr. Taylor's work in this particular direction is wrongly called management. It is scientific *method,* if you will, but not scientific management.

3. We have also used Mr. Gilbreth's suggestive book, "Motion Study," as a class room text. In order to make the matter of economy through planning and potential large savings rather more real to the student, we prefaced the course this year by a simple experiment in which the students participated. This was described under the title, "An Experiment in Motion Study," in *Industrial Engineering* for June. Briefly, the men learned for themselves that simple, inexpensive facilities based upon a correct preliminary plan might reduce labor cost two thirds, while simultaneously producing unexpected incidental savings far more important than that in labor cost. After this, they were in a measure prepared to discuss Mr. Gilbreth's book.

4. While no one could more admire the gospel of Mr. Taylor's preaching than we, and while it is conceded that this preaching is to have economic, sociological and psychological consequences almost measureless, it is also felt that Taylorism, as a management method, does not cover the whole field of management; and that even in its field it is by no means of immediate universal application. Mr. Taylor has himself mentioned an instance in which his methods were too hastily applied. The country is buzzing with talk of scientific management, the latest nostrum. It is a nostrum, if we regard a single school of management as alone scientific. Management is of many varieties, some good, some even scientific—so far as management can be scientific.

We believe, therefore, that a study of Taylorism should be an essential and prominent part of our study of works management; but we also believe that some consideration of management in general should precede that of Taylorism, and that there are problems in management which require extended study along totally different lines.

5. In spite of the short time given to the subject, it has strongly influenced our students in their work with us and after graduation. Many of them, more than we wished, have endeavored to find employment in "efficiency engineering." In no other way have the characteristic defects of young technical graduates been more strongly brought home to them, or have the students been placed in an attitude of such great harmony with modern business conditions. Works management is one of the most valuable courses we have. It is particularly valuable because it is brief and suggestive, rather than a cut-and-dried matter of detail. The students see the point almost from the start.

Mr. Frank B. Gilbreth (by letter): The paper by Professor Hibbard and Professor Philbrick is a sign of the times. There is probably no other educational event of so great importance as the general interest that the engineering colleges are taking in the subject of scientific management. The collection of data regarding scientific management is the natural function of engineering schools, but the greatest good cannot be achieved until there is a co-operation of all colleges, corporations, firms, and individuals connected with, and interested in scientific management. The subject is too great for any one body of investigators, or operators. It is too large for any one section of the country to expect to master. Mr. Henry R. Towne, a member of the American Society of Mechanical Engineers, an expert manager for an unusually long period of years, testified before the Interstate Commerce Commission that any one who has studied the subject of scientific management ten years and imagines that he can make a mental picture of the end of improvements under scientific management is "merely testifying to his own senility."

For the best results there must be co-operation of all teachers, investigators and installers and users of scientific management and there must be a central body where such information shall be classified, catalogued, and put at the disposal of all desiring it. A fitting model for such a department exists today in the United States Department of Agriculture. Such a department should be created at once by the United States government, and similar bulletins should be printed and obtainable at nominal cost as now are to be had regarding subjects relating to agriculture from the Department of Agriculture.* It was in the interests of collecting, preserving, cataloguing and disseminating such information that the Society to Promote the Science of Management was recently formed. Work is already under way toward co-operating with the great library systems, that the subject of management may be recognized as science and catalogued accordingly. At present the most reliable estimate is that there are approximately only 50,000 people operating under scientific management. Inasmuch as scientific management is almost wholly a matter of pedagogy, it is most fortunate, for those interested, that the colleges are now teaching it, for soon there will be available not only those who understand the underlying laws of scientific management, but also those who by their special training and their general education will be best fitted to teach the workmen and functional foremen the actual practice.

In our own work we have revolutionized several trades, especially those that relate to bricklaying, concrete, etc. We have seen time and again difficult practice of the past succumb to easier, less wasteful practice, simply by recording motion and time studies of elements of processes, and then building up new methods synthetically. We are now prepared to state that we have new data of actual practice on brickwork which will again revolutionize our reconstructed practice. There is no end to the subject. A government department for carrying on time study and motion studies of the building trades would, without a doubt, result in reclassifying all the trades, in eliminating much present wastefulness, and in providing higher wages to all classes of workmen. The workers of the country are afraid of such an innovation, for the reason that they believe that government investigations and reclassifying of the trades will be used by unscrupulous employers as a means of lowering wages generally.

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* As an example see U. S. Dept. of Agriculture, Circular No. 110—"Food, Customs and Diet in American Homes," by Dr. C. F. Langworthy, Ph.D. This circular in a way relates to scientific management, in that it deals with the relation of quality of food to output of the worker.

The education of the workman in political economy must also be considered or his co-operation for the advancement of scientific management will not be obtained. (See House of Representatives Resolution No. 90, 62d Congress, 1st Session, "Investigation of Taylor System of Shop Management.") The colleges and the government should disseminate information showing the effect of high outputs and the elimination of unnecessary waste on the general prosperity of the country, for at present there are many workmen in this country, and especially in England who actually believe that the less output each worker accomplishes per hour, the better for all workmen in the long run.

The work of Dr. Frederick W. Taylor as described in the 1907 *Transactions* of the American Society of Mechanical Engineers, "On the Art of Cutting Metals," shows what can be done in one trade. The great strides that have been since accomplished by his followers are described in the literature of today.

The need today is:

1. Laboratory methods of analysis of processes.
2. Standardization of everything, even to the motions that make up the elements of primary processes.
3. Building up synthetically the one best way, from the smaller standards that will eliminate wasted time or fatigue.

In this subject the colleges can do work of great value both of itself and also in turning out efficiency engineers who will be able to improve working conditions in all kinds of organizations.

There is however another great need of a government bureau as described, for the purpose of carrying on an original research work where results, while being of great benefit to those interested, could not be obtained at a reasonable cost by the concerns most needing them if they each undertook the work themselves, not only because of the great cost of such investigation, but because the private concerns could not gather together nor maintain the proper trained corps of specially fitted scientists for this work. There has already been gathered a great amount of data on the subject of scientific management that would undoubtedly be donated to such a department of the government.

Making efficiency engineering a part of the curriculum of the colleges will be of great value for the following reasons:

1. It will enable the student to do his chosen life work better, easier and more profitably.
2. It will fit him for the only uncrowded profession.
3. It will raise wages.
4. It will reduce production costs.
5. It will make the country more prosperous.
6. It will reduce the cost of living.

Dr. Taylor said in June, 1895:*

> "What is needed is a hand-book on the speed with which work can be done, similar to the elementary engineering handbooks. And the writer ventures to predict that such a book will before long be forthcoming. Such a book should describe the best method of making, recording, tabulating, and indexing time-observations, since much time and effort are wasted by the adoption of inferior methods."

There is no longer any reason for delay for we have perfected the method, and the device for making and recording time-study observations mechanically, eliminating all error of the human element.

It is to be hoped that all colleges will contribute constantly to such a book of data, for it is more needed today than ever before.

The Society for the Promotion of Engineering Education is to be congratulated that Messrs. Hibbard and Philbrick have brought this subject to its attention.

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* See *Transactions* American Society Mechanical Engineers, Paper No. 647, p. 68, " A Piece Rate System."

Mr. W. J. Harahan (by letter): I have read the paper by Messrs. Hibbard and Philbrick with a great deal of pleasure. I thoroughly agree with the ideas which it advances and I think that the introduction of such a course in our colleges would prove of vast benefit from a practical standpoint. I think that the authors of the paper have too much fear of it being considered theoretical on account of not having direct contact with actual work. So far as scientific management is concerned, generally, I believe that the efficiency engineer is indiscreet in trying to push it into places where it cannot be applied in its full force, but I believe that in every place it can be applied to a very large extent; in fact, I think that the railroads have done more along the lines of scientific efficiency work than any other line of business has done.

Mr. Harrington Emerson (by letter): Practically we are always engaged in the struggle between principles and methods. The mathematician has principles, the book-keeper, methods, and it is of surpassing importance that the younger generation should learn to apply principles; and where can they learn if not in the colleges?

Professor George H. Follows (by letter): I have read Professor Hibbard's article with especial interest because in our School of Applied Science,* we have for the past five years been giving and developing a course in engineering works management, under conditions that we consider are peculiarly favorable. I believe it will interest many readers of the PROCEEDINGS to know something about our experience in this almost new field of engineering instruction, and what some of our ideas are with regard to its future place in the regular engineering curriculum.

Conditions with us being different from those at the University of Missouri, our methods have developed into something rather different from those described by Mr. Hibbard. In the first place, it is during the freshman and sophomore years that our students do all their shop work, and in our opinion they are not then sufficiently developed to appreciate

* Carnegie Institute of Technology, Pittsburgh, Pa.

as they do later, the course in the science of engineering efficiency and management. Again, our students in their senior year are too heavily loaded with other work to permit of their devoting to actual shop practice the time that would be necessary to carry on, in connection with work of their own hands, production studies of more than the most elementary character.

All courses in shop practice, which as already stated, are taken during the freshman and sophomore years, are of such a nature as to prepare the student for senior work in shop management and efficiency engineering. Several years ago we came to the conclusion that in addition to whatever modicum of skill the student might acquire from his manual practice in the shops, he should become acquainted with many things by means of either experiment or expert demonstration, or both. Thus, to give an example of machine-shop work, the student learns to use the file in connection with a definite set of experiments in which he personally compares the physical qualities of different metals by filing them with different kinds of files; and he writes down his findings, which are afterwards discussed with the instructor. It is not expected that the student shall acquire great skill in the use of the file; nothing but long continued practice would suffice for this. Exhibitions of skillful filing are given by the instructor, who is himself an expert mechanic.

In connection with all work in the machine shop, the idea is not so much manual training as an intelligent understanding of what it is possible for skilled hands to do; what different degrees of accuracy and kinds of work cost; something about the construction of machine tools, the handling, adjustment and care of them, the advantages of different shapes of cutting edges and their treatment.

We believe that the accurate timing of an expert, and the study of his motions, which motions are made and explained especially for the student to observe and time, are of more value than observations of the necessarily crude performance of a student. However, it is during the senior year that the more serious studies of efficiency methods and management are made. Here we believe, after several years of experience, that we are particularly fortunate in being allowed to use as a laboratory, with full privileges, the entire plant of a large, modern, and successful engineering concern. Three years ago the R. D. Nuttall Company, which employs about 400 men and manufactures all types of toothed gearing, generously invited us to have our students use their shops for studies of times, processes, work dispatching, routing, and in fact the entire plant in any way that we chose.

In these shops, the standard machine tools are well represented, up to large capacities; and in addition there are many special tools, used in either the manufacturing or testing of gears. The president, Mr. Estep, and his works manager, Mr. Rupert, have co-operated most heartily, and although there are necessarily one or two processes that we are not allowed to carefully investigate, we may say that practically the work of every man and machine is open for us to study and measure.

Students are handled by a competent instructor, who before joining the staff of these schools had spent his life as a mechanic, designer, engineer, and works manager. Working in small groups, students begin by measuring up different parts of the plant, afterwards making scale drawings of the shops and departments. In turn they study the power house, heating, ventilating and lighting equipments, lavatory and locker-room accommodations, and every department of the shops from offices to shipping department, making notes, sketches and scale drawings. The distribution of power receives special attention, also the handling of materials, timing of cranes, and the work of the move-men. Then follows a critical study of several machine tools with regard to their foundations, installing, lighting, space around, setting up work, etc. Sketches of jigs and fixtures are frequently made. Finally the work of skillful men operating high-grade machine tools is studied in detail; the cutting tools are tested with the scleroscope and compared with shape charts; tables are made of all data, including machine, its capacity, make, tool used, cut, feed, speed, material operated upon, and output as to both kind and grade.

In the class-room a regular course of lectures is given on the science of works management, in connection with which students write weekly theses. The following will give an idea of the ground covered: Analogy of the living Tree and the Manufacturing Plant; Administration Chart for Typical Plant; Plans of a Model Plant, in connection with which a theoretical study of systems is made later; A Typical Routine Chart for small Plant; Complete Routine, covering receipt of Order, Manufacture, and Shipping of a Single Piece; Classification of Charges; Productive and Non-Productive Labor; Depreciation and Repairs; Time and Cost Keeping; Overhead Charges; Hourly Burden; Prime Cost and Selling Prices; Man Work and Machine Work; Manager's Records; Changes in Value of Plant; Production Books; Wages; Day, Piece, Premium, Bonus, and Task Plans; Drawings as Official Documents and their vital importance in any System for Engineering Plants; Drive versus Incentive; Functional Foremen, and the Duties of the Shop Staff; Labor Unions and Strikes; The Scientific Designing of Printed Forms; System and Red Tape; The Developing of a complete but simple System; Committee Work; Social Betterments.

We have found that in order to maintain interest, the work must be handled in a simple and practical way. To illustrate: the difference between depreciation expense and repair expense is made interesting by applying the argument to a pair of shoes and the personal reserve fund. Statistics and arguments that are of great interest and value to a practicing engineer sometimes quite fail to in any way attract or instruct a student.

We have found that it is necessary to insist upon the writing of theses; this work induces interest, especially when it must be done in the student's best literary style.

We believe that the course will hold a permanent place in the curriculum of the school of applied science. Since 1908 when our first class graduated, several graduates have been appointed to responsible managerial positions, and we now frequently hear from them with more or less full accounts of the work that they are doing; these accounts are always interesting and instructive. We are so sure of the value of the course that quite recently a large sum has been appropriated for the building and equipping of a production laboratory for special experimental and research work.

RESULTS OF EXPERIENCE IN TEACHING SCIENTIFIC SHOP MANAGEMENT.*

BY HUGO DIEMER,

Professor of Industrial Engineering, Pennsylvania State College.

The subject of this paper is one in which I have been interested and along lines in which I have been working in the educational field for nearly ten years. At the 1903 meeting of this society, I presented a paper on "Education for Factory Management,"† in which I advocated the teaching of shop time study and factory economics along the lines indicated in the present paper by Professors Hibbard and Philbrick. At the 1907 meeting I advocated a more liberal recognition of the field of industrial engineering by advocating the establishment of courses in industrial engineering.‡ A tentative course in industrial engineering was described in the *Engineering Magazine* in June, 1908.§ This course was briefly described in the paper presented before this society, on "Employers' Requirements of Technical Graduates" by the writer in 1907.||

I am convinced that the correct way to take recognition of the problems referred to is to recognize Mr. Charles B. Going's definition of industrial engineering, as given in his recent book entitled "Principles of Industrial Engineering." His definition is as follows:

> "Industrial Engineering is the formulated science of management. It directs the efficient conduct of manufacturing, construction, transportation, or even commercial enterprises and any undertaking, indeed, in

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* Presented as a part of the discussion of the paper by Professors Hibbard and Philbrick.

† *Proceedings,* Vol. XI, page 151.

‡ Volume XV, page 110.

§ Vol. XXXV, No. 3, page 349.

|| Vol. XVII, page 172.

which human labor is directed for accomplishing any kind of work. Industrial engineering has drawn upon mechanical engineering, upon economics, sociology, psychology, philosophy and accountancy, to fuse from these older sciences a distinct body of science of its own. It does not consist merely in running the power plant or machinery nor merely in devising processes or methods. It consists in co-ordinating all these things and others, in the direction of the work of operatives and using the equipment provided by the engineer, machinery builder, accountant and architect.

''The industrial engineer may have in his organization staff many mechanical engineers superintending special departments—design or construction, or the power plant. for instance—while his own duty is to coördinate all these factors and many more, for the one great, central purpose of efficiency and economical production. The work of the industrial engineer not only covers technical counsel and superintendence of the technical elements of large enterprises, but extends also over the management of men and the definition and direction of policies in fields that the financial or commercial man has always considered exclusively his own.

''Industrial engineering deals with machinery; but not so much with its design, construction, or abstract economy, which are strictly mechanical considerations, as with selection, arrangement, installation, operation and maintenance, and the influence which each of these points or all of them together may exert upon the total cost of the product which that machinery turns out. It deals with materials, but not so much with their mechanical and physical constants, which are strictly technical considerations, as with their proper selection, their standardization, their custody, transportation and manipulation. It deals very largely with methods; but the methods with which it is particularly concerned are methods of performing work; methods of securing high efficiency in the output of machinery and of men; methods of handling materials, and establishing the exact connection between each unit handled and the cost of handling; methods of keeping track of work in progress and visualizing the result so that the manager of the works may have a controlling view of everything that is going on; methods of recording times and costs so that the efficiency of the performance may be compared with known standards; methods of detecting causes of low efficiency or poor economy and applying the necessary remedies. It deals with management—that is, with the executive and administrative direction of the whole dynamic organization, including machinery, equipment and men. It deals with men themselves and with the influences which stimulate their ambition, enlist their coöperation and insure their most effective work. It deals with markets, with the economic principles or laws affecting them and the mode of creating, enlarging, or controlling them.''

I have quoted thus at length from Mr. Going's book in order that there may be a distinct understanding that we who are championing the cause of industrial engineering have no desire to weaken courses in mechanical engineering nor to supplant such courses.

There is no question but that machine shop work, as given in college shops, is capable of great improvement. At the Pennsylvania State College we have carried on a course in machine shop time study for the past three years. I attach to this paper a set of data sheets indicating to what extent the work has become standardized with us as a result of these three years of experience. While I share the enthusiasm of Messrs. Hibbard and Philbrick for everlasting emphasis on principles, I wish to emphasize the fact that a man who would attempt to be an efficiency engineer, depending on principles alone and without experience in methods, would be just as inevitable a failure as the half-baked efficiency engineer to whom the authors refer, who mistakes systems and methods for the fundamental science.

By way of illustrating another portion of our methods, I have attached also a copy of the routing or instruction sheet used in our machine shop, with the simplest exercise in the lathe, consisting of the turning and facing of a small cast iron cylinder. The beginners in machine shop work are not given the time elements which go with the various steps designated in the instruction card. The establishing of time elements is left to the students taking the time study course, who make comparison of their results with figures obtained through the courtesy of a large manufacturing company, who supplied us with the time and other machine data which would be specified for the pieces if they were being run through their shop. We also conduct a planning department and ''Daily order of work'' board in our machine shop.

The point I wish to emphasize particularly, however, is that if we want to carry out Messrs. Hibbard and Philbrick's policy of teaching fundamental principles instead of teaching merely methods, we must recognize industrial engineering as a distinct field and recognize that it demands men of a different temperament than mechanical engineering and that these men must be given an entirely different college course.

The four years' course in industrial engineering, as given at the Pennsylvania State College, prepares the student desiring to enter industrial organizations in positions leading to superintendence, purchasing, selling, scientific management and corporation officerships. It aims particularly to prepare for the bettering of industrial efficiency. It prepares the graduate for the competent handling of such subjects as departmental management in factories, determination of costs, depreciation, manufacturing statistics, proper distribution of expense, economic production, systems of remunerating labor and raising labor efficiency, the handling and recording of stores, stock, and orders, sales, purchasing, planning of production and production methods, corporation accounting, and allied work, leading ultimately to superintendence, works management and general management.

For the purposes indicated well-trained engineers are required; hence the course includes all the fundamental engineering work in mathematics, drawing, physics, chemistry, machine design, heat engineering, mechanics, hydraulics, and structures that are common to all other engineering courses of the School of Engineering. But more time should be and is given to such general studies as industrial economics, logic, and psychology, also to specialized work in accounting, factory management, shop time study, machine tools and methods, factory planning, and more shop practice in general than is offered in other engineering courses. The study of logic, psychology and economics is intended to give the student the underlying foundations for acquiring ability to get along with men as a shop executive, a salesman, purchasing agent or business manager, and to arrange and plan his work logically and systematically. The large amount of shop-work and shop methods, corporation accounting, cost accounting and factory economics, will give him a grasp of these matters which should be of material value in manufacturing processes.

The course offered is in line with replies received from many manufacturers to a canvass of them to get their opinion as to what studies best train for their industries.

Following are a few of the printed forms illustrating some of our methods in connection with the application of the principles of scientific management in our machine shop, namely Tool List, Instruction Card, and Time Study Notes.

My object in exhibiting these examples of what we have done and what we are doing is to present helpful suggestions to others planning to undertake this work and to elicit further suggestions from others along the same line.

TOOL LIST FOR	OPERATION Turn and Face

MACHINE No...DRAW. Nos.....501...............

PIECES	NAME	SIZE	TOOL SYMBOL
	Exercise must be centered with drill and countersink on speed lathe equipped for this purpose.		
1	Carrier	2¼″	
1	Round nose	PP	PRR
1	Side		PUBC
1	Side		PUSG
1	File	12	

The above tool list is handed each student together with the detailed instruction list covering movements and methods, the tools being provided in a box, ready to use, for each individual.

The Pennsylvania State College. Industrial Engineering Department.

INSTRUCTION CARD FOR OPERATION.

SHEETS, SHEET No.		DRAWING No.	MACHINE No.	ORDER No.	
MATERIAL	CLASS No.	PIECES			

DESCRIPTION OF OPERATION

ITEM	DETAILED INSTRUCTIONS	FEED	SPEED	Element Time per Piece	Time for Entire Lot	Continuous or Running Time
1 2 3						

Full size of sheet 8½ by 12½ inches.

38					
		MONTH	DAY	YEAR	SIGNED CHECKED

LIST OF OPERATIONS APPEARING IN COLUMN OF DETAILED INSTRUCRIONS FOR THE OPERATION OF LAYING OUT AND DRILLING CENTERS.

(1) Change card. (2) Learn what is to be done. (3) Remove fins or roughness from piece on emery wheel. (4) Grind scale from ends before centering. (7) Put piece in vise and clamp. (8) Chalk one end. (9) Find center of one end with hermaphrodites. (10) Punch where marked with center punch. (11) Turn piece end for end in vise and clamp. (12) Repeat items 7 to 10 for other end. (13) Take piece to speed lathe. (14) Put centering drill in chuck. (15) Put one center punch mark in tail stock center. (16) Bring the other center punch mark to drill. (17) Start machine. (18) Drill hole 3/8″ deep. (19) Repeat items 15 to 18 for other end. (20) Stop machine. (21) Remove drill, put in 60° countersink. (22) Change speed (slower). (23) Put one drilled hole on center in tail stock. (24) Bring other hole to countersink. (25) Start machine. (26) Countersink hole to 5/16″ dia. (27) Back piece from countersink. (28) Repeat items 23 to 27 for other end. (29) Take piece from machine and clean, put tools in proper place. (30) Take piece to your assigned machine. (31) Set machine and see that centers are true. (32) Put carrier on one end of piece and tighten. (33) Clean centers in both ends of piece. (34) Put piece in machine and oil tail stock center. (35) Adjust machine and put in backgears. (36) Put PUBC or PUSC in tool post. (37) Adjust tool and tighten same, tool to set 15° to the left. (38) Start machine.

LIST OF OPERATIONS FOR TURNING AND FACING.

(1) Face end, remove all scale with first cut. (2) Finish facing with 2d cut, take 3d cut if necessary. (3) Stop machine. (4) Reverse piece. put carrier on other end. (5) Put piece in machine oil, center on tail stock end. (6) Start machine. (7) Repeat items 1 to 3 for other end. (8) Make length of piece exact size on print. (9) Stop machine and measure. (10) Remove tool, put in PRR. (11) Set tool about 15° to left and tighten same. (12) Start machine. (13) Move tool to the piece at tail stock end. (14) Rough turn piece to within ½″ of carrier and make 2 3/32″ dia. (15) Stop machine. (16) Reverse piece, put carrier on other end. (17) Put piece in machine, oil center on tail stock end. (18) Start machine. (19) Rough turn balance of piece to 2 3/32″ dia. (20) Stop machine, see if tool is sharp. (21) If sharp finish turn to within ½″ of carrier. (22) Stop machine. (23) Reverse piece, put band of copper on finished end, clamp carrier on same. (24) Put piece in machine. (25) Start machine. (26) Finish turn balance of piece to 2 1/16″ dia. (27) Stop machine gauge and measure. (28) Clean machine. (29) Remove carrier from piece and put on rack. (30) Clean piece and stamp your number on same.

Note:—Place piece together with instruction cards, print templates and gauges on desk in the office.

We have extended the principle of detailed instruction sheet and motion study to the forge shop also. The following list is taken from the instruction sheet for standard exercise No. 1. The department is working out similar sheets for instruction in wood shop operation and foundry exercises. By the close of the present year we hope to have all of our present series of shop exercises standardized.

List of Operations for Heating and Bending Wrought Iron (3 Inch Ring).

(1) Clean all clinkers and ashes off tuyere. (2) See that tuyere holes are clean. (3) Try blast (see that it is free). (4) Place 3″ wood pin on tuyere. (5) Pack green coal tightly around pin. (6) Draw pin out. (7) Put shavings or oily waste on tuyere. (8) Light shavings or oily waste. (9) Turn on small amount of blast. (10) Put crushed coke on lighted shavings. (11) Turn on more blast. (12) Put more coke on fire. (13) Get stock (1 pc. ¼″ rd. 10¼ in. long). (14) Put stock in fire. (15) Heat stock yellow heat 1″ from end. (16) Remove stock from fire with flat tongs. (17) Square up end of stock with hammer. (18) Reverse stock and place it in fire. (19) Heat stock to yellow heat. (20) Remove stock from fire with flat tongs. (21) Repeat operation 17. (22) Place stock in fire. (23) Heat stock to red heat 2/3 length of stock. (24) Remove stock from fire with flat tongs. (25) Bend stock half-way round horn of anvil. (26) Reverse stock and place in fire with flat tongs. (27) Heat to red heat. (28) Remove stock from fire (flat tongs). (29) Bend straight end around horn of anvil. (30) Complete exercise on horn of anvil or mandril. (31) Have piece inspected. (32) Fill out work card and tie to exercise. (33) Put finished exercise in box for finished work. (34) Return this instruction card and blue print to proper place. (35) Get instruction in card and blue print No. 2. (36) Read same carefully.

The detailed instruction sheets showing minutely all motions and methods, are furnished with the blue-prints of the exercises during the first half of each semester's shop course. Our experience has been that the student finishes these pieces under this system in about two-thirds of the time formerly taken, without the system. During the second half semester each student works without the tool list and instruction sheet, and in addition to performing the exercise, prepares a tool list and detailed instruction sheet himself, which is then corrected by the instructor. The Time Study work is given only to those taking the Industrial Engineering Course. The following notes will indicate the nature of this work:

TIME STUDY NOTES.

Read over carefully before beginning work.

1. Make sure that there is at hand all of the following equipment before beginning work: watch, stop-watch, cutmeter, speedometer, balances, or scales, set of weights, calipers, 12-inch scale, and materials for recording.

2. Begin to take time when operator starts to get stock, and keep accurate record of every second until piece is finally completed. All time must be accounted for.

3. While operator is getting stock, prepare scales for weighing and have instruments at hand for measuring. Insert sketch of piece in rough in the proper place.

4. Before starting to machine the piece, both operator and observer must carefully examine machine, see that centers are in line, become familiar with each handle, knob or lever connected to the machine, together with the different actions of the machine when any one of these are adjusted. After this, the operator will oil the machine wherever there is a cup or hole for same.

5. After roughing cut has begun, take cut meter and speedometer readings and record; then sketch and measure cutting tools not then in use. In this manner, keep abreast of the operator in order that an accurate and full record of all procedure may be had. Don't forget to weigh after each operation.

6. The observations on each separate experiment must be computed and recorded, presented to the instructor in charge, and receive his approval before the next experiment in the series is begun. Be sure that you have the time per cubic inch and per lb. for each operation completely figured on one piece before going to work on another piece. A copy of the correct computation must be kept on the back of the recording sheets as a check upon errors.

INSTRUCTIONS TO OPERATOR.

1. The observer as well as the operator must use extreme care in making time studies, to see that the proper sequence of operation is maintained, and all unnecessary operations or moves are eliminated. Also that the most economical combinations of speed, feed and cut are used, as well as the most suitable tool for each operation. If at any time, the observer is in doubt as to the correctness of time on an operation, the

operator on request of the observer, will repeat any or all operations desired.

2. Do not start for stock until observer has everything in readiness for the experiment.

3. Do not fail to keep observer fully informed of every detail of procedure, so that a perfect record of the experiment may be made. The operator can help materially in this.

4. Do not fail to weigh the piece after each metal-removing operation and have the observer record the weight.

5. See note 6 above.

Time observations to be taken in minutes and decimals of a minute.

Weight observations to be taken in lbs. and decimals of a lb.

Measurements to be taken in inches and decimals of an inch.

The weight of a cubic inch of cast iron is .2604 lb. (Kent).

The weight of a cubic inch of steel is .2833 (Kent).

The values of seconds in the decimal of a minute are as follows:

Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.	Sec.	Min.
1	.017	11	.185	21	.350	31	.517	41	.683	51	.850
2	.033	12	.200	22	.367	32	.533	42	.700	52	.867
3	.050	13	.217	23	.383	33	.550	43	.717	53	.883
4	.067	14	.233	24	.400	34	.567	44	.733	54	.900
5	.083	15	.250	25	.417	35	.583	45	.750	55	.917
6	.100	16	.267	26	.433	36	.600	46	.767	56	.933
7	.117	17	.383	27	.450	37	.617	47	.783	57	.950
8	.133	18	.300	28	.467	38	.633	48	.800	58	.967
9	.150	19	.317	29	.483	39	.650	49	.817	59	.983
10	.167	20	.333	30	.500	40	.686	50	.833	60	1.000

Formulas for Computation.

Given: K = weight per cu. in. of material.
T = time elapsed at a given operation.
A = weight of metal removed at the given operation.
I = time per cu. in. of metal removed.
P = time per pound of metal removed.

Then

$$I = KT/A$$

and

$$P = T/A.$$

If it is impossible to secure decimal weights in avoirdupois, weigh the piece by metric weight and convert to lbs. by the following:

I kg. = 1,000 g. = 2.20462 lbs. avoir. (Kent).

This will give accurate weight.

1. Std. roughing and finishing tools to be used.

2. Roughing cut or cuts to be deep as possible.

3. Speed of spindle to be fast as possible.

4. Feed of carriage to be fast as possible.

Note.—Nos. 2 to 4 must be found by trial, and are satisfactory only if the roughing tool is ready for re-sharpening at the completion of the exercise. Care must be taken that the speed of the spindle is not too fast, for in this case the temper of the tool will be drawn (tool burned) making it impossible to use again before forging and tempering.

5. Slower spindle speeds and faster feeds for roughing work should be used.

6. Faster spindle speed and slower feed for finishing work should be used.

7. Exercises must be permanently centered and countersunk.

8. All gates and fins must be ground or chipped from castings before centering.

9. When turning work, cut must be sufficiently deep to remove all scale.

10. Both ends of the piece must be faced before starting to turn.

11. When facing work never allow stub end of center to remain, face completely across ends of work.

12. Always rough the entire piece before starting to finish it.

14. Allow 1/32″ for finish on cast iron and 1/64″ for finish on steel.

15. Before clamping dog or carrier on finished piece of work, put band of copper around the work to prevent marking or dents.

16. Never lay lathe tools or file on lathe shears.

17. When filing work, see that no parts of machine are in motion except lathe spindle.

18. For filing steel, run spindle at highest speed, also for polishing same.

19. For filing cast iron, run somewhat slower than for steel; for polishing, run on same speed as for polishing steel.

20. Always clean file with stick or brush, never rub hand on file.

21. When filing, never touch work with your hand.

22. Always take measurements from one end of work only.

23. Use cut meter for surface speed.

24. Use speedometer for spindle speeds.

25. Use stop watch for each operation.

TIME STUDY DATA.

Exercise No............. Machine No.............
Date Started..........Date Finished..........Time Req'd..........
Observer..................Box No...........Group Letter..........
Operator...................................
Wt. Rough..........Wt. Finished...........Wt. Removed...........

(General Data)

Sketch of Rough Piece: Sketch of Finished Piece:

Note.—Fill in the space below the condition of each tool, after each operation; also the reason for the condition the tool is in.

If changes were made from original tool list, give reasons for it. If tools had to be re-ground or retempered, record here.

Further remarks:

Operation. Steps.	Surface Speed.	Spindle Speed.	Feed.	Depth of Cut.	Weight Piece.	Time.		
						Start.	Finished.	Elapsed.
1								
2								
3								
etc.								

Exercise.......... Group Letter.......... Machine No...........

Extra blank sheets covering individual operation data are furnished, the student being encouraged to get too many rather than not enough operation data. The individual data are then collected into a summary, as below:

Summary: Group Letter............

Give a list in proper order of all operations in which metal was removed, stating whether emery grinding, roughing, finishing, facing, boring, thread cutting, drilling, planing, and a total of time for all like operations, etc.

Actual time spent in *removing metal only* to be listed separately:

	Time.	
	Hours.	Minutes.
Grouped Operation No..........................	....	....
1.	....	....
2.	....	....
3, etc., to..................................	....	....
10.	....	....
Time getting material........................	....	....
Time weighing................................	....	....
Time getting tools...........................	....	....
Time grinding tools..........................	....	....
Time setting up..............................	....	....
Time spent in other operations...............	....	....
Total time (should check with Sheet 1).....	....	....

Group Letter............

Weight of material per cu. in. ....

Total weight of material removed ....

Cubic inches of material removed ....

Give total time for all like operations ....

Give total weight ....

Operation No.	Total Time Removing Metal by This Operation.	Total Wt. after This Operation.	Total Wt. Removed by this Operation.	Time per Cubic Inch.	Time per Pound.
1.					
2.					
3.					
Etc.					

Time of getting ready per cu. in...................per lb...........

Time of tool grinding per cu. in....................per lb...........

Time of active metal removed per cu. in..........per lb...........

All other time ....per cu. in..........per lb...........

Total time ....per cu. in..........per lb...........

GRADUATE COURSES IN HIGHWAY ENGINEERING AT COLUMBIA UNIVERSITY.

BY ARTHUR H. BLANCHARD,

Professor of Highway Engineering, Columbia University.

The status of highway engineering in the United States was ably presented before this Society at the New York meeting in 1909 by the Hon. Logan Waller Page, Director of the United States Office of Public Roads. As stated by Mr. Page, many years will elapse before the supply of thoroughly trained highway engineers will exceed the demand. The conditions existing in 1909 have not been materially improved during the past two years.

The technical graduate who is attracted to highway engineering has several more or less well defined fields open to him, namely: the highway departments of municipalities and towns; those of states, counties and parks; the engineering organizations of contractors; and the engineering and sales departments of companies dealing in materials and machinery used in highway work. In city and town work, matters relative to the construction and maintenance of streets and pavements compose the bulk of the work assigned to the highway departments together with more or less road engineering problems. With state, county and park departments, the construction and maintenance of all types of road surfaces and bituminous pavements constitutes ninety per cent. of the work of such organizations while certain problems in street pavements and highway bridges have to be dealt with occasionally. The prevailing idea, however, that the two fields just mentioned are easily separable and that the preparation for one should not be the preparation for the other is essentially wrong. Since the lines of demarcation between the above fields are rapidly becoming obliterated, the successful highway engineer of to-day, whether engaged by the city or state, must have a comprehensive knowledge of all branches of highway engineering and allied subjects. Otherwise it is obvious that it will be impossible to follow that important principle of economics of highway engineering, the adaptation of methods and materials to local conditions.

In contemplation of these opportunities, the essential prerequisites of a successful career as a highway engineer must be given due consideration in order that the future prospects offered by this field of engineering may be thoroughly understood.

The ideal foundation consists, first, of four years' training in a course in civil engineering; second, practical experience in both field and office in connection with the construction and maintenance of roads and pavements on a system of highways; and, third, the acquisition of knowledge along certain lines of particular value to the highway engineer.

In explanation of the last prerequisite it might be stated that to be well informed the highway engineer must acquire considerable knowledge relative to the economics of highway engineering, materials of highway engineering, management engineering, highway laws and systems of administration, mechanical appliances used in highway engineering, highway bridges and culverts, road and street surveying, drafting and designing, methods used in a road material laboratory, advanced dynamic and structural geology, lithology, petrology and petrography, processes of industrial chemistry, methods of testing bituminous materials and the interpretation of results, and finally, advanced highway engineering covering the most recent practice throughout the world in the construction and maintenance of all kinds of roads and pavements.

The fulfillment of the first two prerequisites mentioned is easily accomplished except that the graduate of one or two years' standing may with difficulty retain his position during the months from December to March inclusive, especially if he is connected with a state or county department or the organization of a contractor. In these fields of highway engineering the immense amount of work to be completed during the construction season in the north requires the maximum engineering force obtainable both in the field and in the office, while during the four months mentioned above, the natural confinement of a large percentage of the work to the office necessitates reducing the engineering staff. The prospect of being without work for four months of the year has prevented many high-grade technical graduates from entering the field of highway engineering. In certain cases it has been possible by coöperation between state highway departments and colleges giving courses in civil engineering to mitigate the evils of this situation. As a concrete example may be cited the writer's experience while he was Deputy Engineer of the State Board of Public Roads of Rhode Island. Many of the best civil engineering students at Brown University were employed throughout the college year part time and during vacations all the time, year in and year out, with the natural result that upon graduation some became members of the permanent force. At all times, however, the office force consisted of trained men of a number commensurate with the work of a given season. It should be said that in many cases this plan will not work out satisfactorily for the field or inspection force, due primarily to the fact that while the construction season extends from April to November inclusive in certain sections of the country, the long vacations cover only June to September inclusive, hence the impracticability of utilizing undergraduates, resident at the University, in the months of April, May, October and November in the above field positions.

The third prerequisite mentioned might, of course, be covered by collateral reading, but it is self-evident that only a very limited idea of certain of the subjects mentioned can be acquired in this way. Especially is this statement applicable to over fifty per cent. of the subjects which, it is apparent, must be illustrated and exemplified by laboratory equipment and well stocked museums or developed through the medium of research library work. The United States Office of Public Roads, through the medium of its corps of civil engineering students, offers a method by which a limited number of men may receive training in the construction of roads and instruction in various subjects related to highway engineering. However, as Mr. Page stated in 1909, "this plan will provide but a small percentage of the engineers that will be required."

The problem before the educational institutions of this country is that of determining by what method the subjects outlined above can be offered upon a practical basis. The writer does not favor a four-year undergraduate course in highway engineering, not only because of the varied and potent reasons which have been presented to this Society on various occasions with reference to specialized undergraduate courses, but also because undergraduate students are not sufficiently mature to acquire the benefits which should be derived from a combination of practical experience and specialized knowledge.

The most practicable plan is to arrange a definite course of instruction as a unified graduate course based on the assumption that the technical graduates enrolled for the Master's Degree will hold undergraduate degrees in civil engineering. If the graduate instruction is to be given in the period from about December 1st to about April 1st it will be possible for practicing highway engineers, especially first, second, and third year graduates, to use the winter period advantageously in acquiring advanced knowledge under favorable circumstances.

It is gratifying to the highway engineering profession and that portion of the public interested in the development of good roads and streets throughout the United States that Columbia University should have decided to establish graduate courses in highway engineering based upon a most comprehensive plan embodying the principles enunciated above.

The new graduate courses to be offered at Columbia next year will cover the field of subjects referred to previously in this paper and will in amount be sufficient to satisfy the requirements for the Master's Degree. As the period of attendance will be from December to March inclusive, equivalent to about one semester, two periods of residence will be required to fulfill the requirements for the Degree.

The tentative arrangement of the graduate courses to be offered is as follows:

First Year.

Processes of Industrial Chemistry,
Dynamical and Structural Geology,
Advanced Highway Engineering,
Materials of Highway Engineering,
Seminary in Current Highway Engineering Literature,
Lectures by Highway Engineers, Chemists and Other Experts,
Mechanical Appliances Used in Highway Engineering,
Highway Bridges and Culverts,
Road Surveying, Drafting and Designing.

Second Year.

Industrial Chemical Laboratory,
Lithology, Petrology and Petrography,
Advanced Highway Engineering,
Highway Laws and Systems of Administration,
Seminary in Current Highway Engineering Literature,
Lectures by Highway Engineers, Chemists and Other Experts,
Road Material Laboratory,
Management Engineering,
Street Surveying, Drafting and Designing.

As the special staff of instructors has been appointed and as the various laboratories required will be completely equipped in the near future all the advanced courses in highway engineering and allied subjects as outlined in the above schedule will be open to properly qualified persons next December.

It is of interest to note that this plan has the enthusiastic support of many of the foremost highway officials and engineers in the United States. All emphasize the feasibility of granting four months' leave of absence to practically all the young civil engineers who wish to take graduate courses in highway engineering. It is the hope of those interested in the higher education of highway engineers in the United States that it will be possible in the near future to lay the foundation for the establishment of a corps of highway engineers comparable to that admirable body of trained men who have graduated from l'Ecole Nationale des Ponts et Chaussées of France.

Discussion.

Maj. W. W. Crosby (by letter): The writer wishes first to express his deep appreciation of the effort being made by Columbia University and Professor Blanchard to improve present conditions in highway engineering and to wish them both the utmost success in their efforts. Further, he believes that much good will result from these efforts, which to him seem the most logical as well as practical of any of the sort yet begun.

Professor Blanchard refers, with disfavor, to specialization in undergraduate courses and the writer cannot forbear accenting this point. In the past few years, a number of institutions have established an undergraduate course in highway engineering. This has evidently been a well meant aid to the profession but, in the opinion of the writer at least, the result, or any result possible from such a course of action, will be a heavy detriment rather than an aid. Arguments along this line have probably already been presented to the Society. Consequently, the plan of Columbia University for requiring a bachelor's degree for admission to the course in highway engineering has the approval of the writer. Such a foundation is none too expansive on which to rear a specialty requiring as great a breadth of mind and action, as do the demands on a highway engineer. The period for the instruction to be given is well chosen and the tentative arrangement of the courses seems admirable. Perfection in the latter will probably be a matter of evolution rather than of prescription. If now the younger engineers of the country can be made to see, as the writer believes he does, the possibilities now opened to them along the line of highway engineering, then there is no doubt but that the hope expressed by Prof. Blanchard will be realized.

In this connection, the writer invites the attention of this Society to the following:

May not Mr. R. T. Crane have considerable truth on his side when, in arguing against college education, he accuses college men of too often lacking industry, perseverance and practicality? May not these deficiencies exist, to a certain extent at least, because, as State Superintendent of Public Instruction L. L. Wright, of Michigan, says, of too many vacations? If so, then Columbia is doing her part along a line to meet this also. The writer has for years attempted, as far as his opportunities offered, to assist on the other end of the line,—*i. e.,* by employing men during their vacations. He is convinced that were young engineers accustomed to working steadily and ambitiously from the beginnings of their courses in the high schools either in the study, laboratory, class room, or in the field, with vacation allowances varying from one-quarter of the present time in the earlier years, to one-eighth in the later days of college life, not only would most of the objections now raised by their employers disappear, but also would the interests of the profession and of the men themselves be wonderfully advanced.

From his experience as an employer, however, the writer feels constrained to state that too large a number of the young college men available for his work have seemed to lack either breadth of view, as a result of too narrow and specialized training, or persistent industry as a result of too much play during the later years of their education.

Mr. Nelson P. Lewis (by letter): The information contained in Professor Blanchard's paper on the status of highway engineering in the United States and the plans of Columbia University for graduate courses in this subject are gratifying. The author of the paper very properly insists that these courses should not be given to undergraduate students, and he would discourage undergraduate specialization, the efforts of our technical schools along this line being commended. Such specialization places serious limitations upon the general usefulness of the engineer. If the courses outlined by the author of the paper are subject to any criticism, it may be that they fail to emphasize the economic and other considerations involved in the proper location of highways. It may be assumed that the graduate engineer has acquired mental habits which will induce him to give due weight to these considerations. The average engineer, however, does not appear to appreciate the important relation existing between urban and rural highways; in fact, the American engineer has been slow to realize the inter-dependence existing between a great city and the country about or behind it, and in no one respect is this inter-dependence so great as upon their highways. Perhaps the only real education in this particular phase of the highway problem is to be acquired by observation and careful study of the conditions existing and the results of intelligent planning in other cities and countries. To relatively few, however, do such opportunities come, and the next best thing is reading and conversation with those who have made a special study of this subject.

It is true that the field of the highway engineer is commonly supposed to be restricted quite closely to problems of construction and maintenance and the organization required for this work, and that questions concerning the location of our highways and other details relating to a highway system shall have been determined long before the time for construction or reconstruction in accordance with modern methods. Unfortunately, this is not the case, and this most important phase of the highway problem has been greatly neglected. Columbia University and the incumbent of the new chair of highway engineering are to be congratulated upon the establishment of the graduate courses in this subject.

Professor Hugh Miller (by letter): Professor Blanchard has proposed a most interesting course of instruction in highway engineering. Advanced work in this branch of engineering must necessarily be carried on along different lines from those that have been applied to other branches. It is essential that the highway engineers of the future obtain a more thorough grounding in the underlying principles of their profession, in order to hold the confidence of the public. There are many practical men who believe that they know as much, or more, about road building than any engineer, and there is considerable justification for their belief, because many engineers who have undertaken this work have not been fitted either by training or experience to do so.

On the other hand, those who have specialized in highway engineering have usually only had a course in general civil engineering, in which only a very limited amount of time can be devoted to the studies which are of first importance to the highway engineer. A little geology and mineralogy, a few tests of asphalt, cement and rocks, and a brief course in roads and pavements is a pretty meager foundation for work which requires such an intimate knowledge of the many materials used, and their action under widely varying conditions. The economic problems involved in highway work are vastly different from those presented in other branches of engineering, and call for the exercise of great judgment. The result has been that graduates in civil engineering, who have specialized in highway work have soon reached a point beyond which they advance very slowly, if at all, and except for a few of extraordinary ability, they have become little better than the practical man without engineering training. It is important, however, that the highway engineer should have a complete course in civil engineering, for he must thoroughly understand the principles of hydraulics, drainage and structures.

The arrangement of the time for the courses at Columbia, (four winter months for two years) is an excellent one, enabling those engaged in highway work to avail themselves of the privileges at a time when they are free to do so. This applies at least, to those in the North, from which section Columbia would be most likely to draw her students.

A feature which might be introduced into such a course, which would be very valuable, it seems to the writer, is some training of the students in public speaking, so that they could present the arguments for good roads and influence public opinion in favor of wise and economic road building. The civil engineering students of the department of public roads are obliged to make good roads speeches, and, it is certain that ability along this line would be an important addition to the equipment of the highway engineer. This could probably be carried out in connection with the seminary courses, outlined by Professor Blanchard, and it is possible that he plans to do so. Of course, ability to make a good speech is a great asset to engineers in various branches of the profession, but it seems particularly important for the highway engineer at this time.

It is to be hoped that all young engineers engaged in highway work will see the important advantages to be gained by taking such a course as is now offered at Columbia, and that many will avail themselves of the privileges there offered.

Mr. Harold Parker (by letter): The subject of graduate courses in highway engineering at Columbia as outlined by Professor Blanchard is of absorbing interest to those of us who have been in a position to need the service of trained and experienced men for the construction and maintenance of highways, whether in state or municipal service.

The situation, as it seems to me at the present time, is this: that all engineers who wish to become fitted for highway work must, in fact, begin their training at that period when they start actual practice of that profession and many years of work in the different departments of highway practice must be spent by them before they become fitted to take charge of this kind of work.

I have found in my own experience, that although I could get civil engineers well fitted for all the work ordinarily required of a civil engineer, I could not obtain a man fitted for highway work until years of practice in the field had rendered him an efficient and useful administrator. This has been the experience of practically every commissioner who has had charge of state work and of those who have the street department in a municipality under their charge as well.

It is the practice to advance men in state or city departments as they acquire knowledge of construction, therefore would it be of the greatest practical value if this necessary knowledge was taught collectively and efficiently in a course of engineering education under the tutelage of instructors fitted for such responsibility.

Where the knowledge to which I refer is acquired by practice alone, the engineer, however well trained in ordinary civil engineering, as highway engineer can only acquire the knowledge to which I refer by chance opportunity or by following one line at a time and thus it may be that many years are required to fit him for general highway practice or, in fact, a life so spent may not bring to him the desired knowledge.

I think, therefore, that it is desirable if not actually necessary that the technical schools should establish departments of highway engineering for a graduate course with the special purpose of instructing young men along proper lines of highway work, and this should cover the construction of all kinds of roads and their maintenance, laying of pavements, highway bridges and culverts, treatment of drainage, treatment of surface after construction and during construction, the character and geological structure of materials and understanding of so much practical chemistry as will enable him to understand laboratory methods and test their significance, surveying and training along highway lines and administration.

With such training as this implies and which can only be properly obtained by technical education and with the experience that comes only with actual practice in the field, an intelligent young man may be sure of as good opportunity for steady employment as in any other branch of engineering profession. There appears to me no doubt that the demand for this sort of man is so rapidly increasing that the supply will fall far short of the demand. I don't believe the United States Department of Public Roads is producing men for this purpose, either sufficient in number or adequately trained. The training in that department tends, as it seems to me, toward the development of advocates for the benefits to be derived, rather than toward the development of practical road builders.

Only one conclusion seems to be possible and that is to follow a plan substantially as outlined. By such organized method of preparation can we hope to reach as high a standard of excellence as has been reached in France in this the present model for organization and economy.

Mr. John R. Rablin (by letter): There is no doubt that, with the rapidly increasing demand for good roads throughout the country, there is at present and will be in the future a great demand and a wide field of opportunity for highway engineers. As in all other branches of engineering, to attain the greatest proficiency, it is necessary to specialize in this branch, and the men who do so specialize will be the ones most in demand for highway work.

The opinion has been expressed by some men prominent in highway work, that in the greater proportion of this class of work, engineering services are unnecessary. The writer most thoroughly disagrees with this opinion and considers it as very poor economy for any highway work to be undertaken and carried out without the most expert engineering advice and supervision. Although it is essential that a man should have knowledge in all branches of engineering for highway work, it does not seem absolutely necessary that he shall have taken a degree in civil engineering before he is qualified to take a special course in highway engineering, as appears to be implied in the paper under discussion. If a young man has had some engineering education and two or three years' practical experience in general engineering work, is he not qualified to undertake the special study of highway work, with a good prospect of becoming a thoroughly trained highway engineer?

The proposed plan of a course in highway engineering, to be taken during the winter months of the first few years of practice, is, in the opinion of the writer, most commendable, both from the fact that the men in the lower grades of engineering service can be conveniently granted leave of absence during that period when construction work, especially that on highways, is generally suspended, and also that the student, after having some practical experience and during practice, can acquire the knowledge to much better advantage.

Mr. Philip P. Sharples (by letter): Highway engineering in the United States is at present going through the same change that civil engineering went through in the latter part of the nineteenth century. A period of guess work, of sloppy work, of rule-of-thumb work was supplanted by science, by engineering skill, and by good workmanship. The requirements for the new era in civil engineering are well set forth by George S. Morison, the bridge engineer, in his little book "The New Epoch." The words with no change are applicable to the present requirements in highway engineering. He says in part:

> "The civil engineer of the new epoch, the epoch which he is bringing into existence by the manufacture of power, must be an educated man. In no profession will this be more necessary. The physical laws of power and strength are mathematically exact and admit of no trifling. As the epoch progresses the requirements for each individual will become more complicated. The theologian and the metaphysician may claim that an education based on the laws of matter leaves out the highest part of existence; the biologist and the physician may claim that matter endowed with life is a higher organism than the inanimate matter with which the engineer has to deal. But however true these claims, their laws have not the mathematical rigidity, the clear definition, and the thorough discipline which mark the laws with which our profession works. The engineer cannot shield himself under doctrines or theories which he accepts but cannot understand. Dealing with accurate, definite laws and guided by the corrective touch of physical nature, the education of the engineer will become more necessary, more thorough, and more exact than that of any other professional man. This is the training which the civil engineer of the new epoch must have. This knowledge he must have, or he must be classed as a workman rather than a professional man. . . . The civil engineer of the new epoch must be a specialist. No man can learn to design all the tools by which the

powers in nature are to be directed. The work is too great for one man to master. The best results will only be obtained by concentrating effort in a single line. But though the civil engineer must be a specialist, his specialty must not be of a narrow kind; he must have that general knowledge and training which makes the liberally educated man. In every occupation a natural selection of men takes place; some follow the close lines of the work for which they are trained, while to others this training is but an incident in the early part of their careers, and does little more than point the general direction of their lives. The ability to deal with men and to direct the minds of men is a matter of natural gift more than of education. It is so important that when possessed in a high degree, all other accomplishments yield to it; and its possessor, realizing that the ability to use several minds gives him the same advantage among his fellows that the control of additional power has given among races, will use his capacity. But the positive training of an education has its value for men whose paths of life may lie far from the special work for which they were trained; it will at least teach them the importance of accurate knowledge. Too many men are contented to guess rather than to know, relying on personal tact to relieve themselves from difficulties when their guesses are wrong.''

The establishment of a highway engineering course at Columbia University is at this moment especially timely. Engineers themselves are many of them much confused at the mass of data, of new problems and their solution that has been forced upon them by the change from horse drawn to motor vehicles during the past half decade. It has led some of them to distrust themselves. The state engineer of New York, Mr. John A. Bensel, went so far as to say at the Rochester, N. Y. road convention:

''It cannot, I think, be claimed that there is as yet a sufficient amount of data to place roadbuilding in a definite class of engineering. Some engineering work has to be done in connection with the work, but the lack of definite data to reduce it to a science can be understood from an inspection of the work in the various states, where a larger variation could probably not be made, even if it was desired to vary for the variation itself.''

This congested state of mind cannot be but a passing phase and the way is already open for true knowledge and true science in road engineering problems. A more intimate cooperation of the chemist and the engineer is called for to solve our modern day problems. Professor A. H. Blanchard has clearly seen the present requirements and his list of courses for two years of graduate work is admirable in every respect. To Professor Blanchard, returning from a year spent in studying the road situation in Europe, and already conversant with the work done in the United States, the needs of the highway engineer of the new era were very apparent.

The plan of presenting courses for the winter months only is new to American colleges and is to be particularly commended, as it is so well adapted to the requirements and the convenience of the young road engineer.

Two other features which are novel and should meet with much favorable comment are the seminaries in current highway engineering literature and the course in management engineering. Many of the subjects of most vital importance to the highway engineer are so new that current literature is the only literature available. Through consulting the proper journals the young engineer will learn the importance of watching what his fellow engineers are doing, and will perhaps learn to know what value to put upon articles that appear in current literature. Management engineering is an all important but much neglected topic. The recent awakening under the title of scientific management is bringing the subject into prominence in factory management. The field is just as broad and the results are as far reaching in road engineering.

It is to be hoped that the courses in road engineering at Columbia University will meet with the hearty co-operation which they merit, of all engineers and others interested in the problem of good roads. Those in authority should take it upon themselves to urge their promising young men to take these courses.

Professor Leonard S. Smith (by letter): Professor Blanchard's plans for a broad training in highway engineering appeal to the writer as being based upon a sound conception of the actual conditions and needs now confronting the states east of the Alleghany mountains. In the older, and by far the greater, part of the United States, railroad construction has proceeded far in advance of highway construction. The result has been that in many cases the cost of transporting farm products from the farm to the railroad station exceeds the cost of rail transportation to the distant consumer. But, aside from any money consideration, political and social needs of our people fully justify extensive highway improvements. The records of the past five years make certain that the near future will see the expenditure of vast sums of money in road construction and maintenance. For if even ten per cent. of our 2,500,000 miles of country highways are to be improved at the modest cost of $4,000 per mile, the total cost of such work reaches the enormous sum of one billion dollars. The present improved method of maintenance of such a mileage would involve an annual cost greatly in excess of $100,000,000. The simple statement of such enormous figures is most significant.

The writer knows of no other field of engineering endeavor so full of promise to the engineer or of such importance to the country's progress. He feels like congratulating the engineers who find it possible to avail themselves of Columbia's advanced courses in highway engineering. Similar courses are certain to be duplicated by western universities as soon as highway construction assumes the importance here which it now has in the older eastern states. This prediction is based upon the really remarkable way in which these progressive institutions have responded to the needs of their respective commonwealths. Already the importance of highway construction has been recognized by the leading western universities, though not to the extent of offering formal graduate courses.

While such courses may be well designed to fit the conditions and needs of the East, the writer very much doubts if such is now true in the Middle West. For some time at least, western technical schools will prefer to provide for courses in roads and pavements as free electives in the Junior, and especially in the Senior years of a civil engineering course.

Such courses, especially the more advanced, would also be available to the increasing number of candidates for the master's degree.

Our people have been strangely slow to realize that even a broken stone road was an engineering structure which required the supervision of experienced and thoroughly trained engineers. The inevitable result has been that immense sums of money have been frittered away in poor design and construction. The times are ripe for a change.

The advent of the automobile traffic, while it has lengthened the life of hard city pavements, has been the chief cause of destruction to all forms of macadam. The seriousness of this road problem is seen when we reflect that the demands made by this new form of motor traffic are certain to greatly increase in the future. Highway engineers of every land are looking for an adequate remedy, but so far with indifferent success. While constructional methods in nearly every other line have been satisfactorily perfected and standardized, we find present highway construction grossly inadequate for even today's traffic.

Again the present practice of unloading this burden upon our children's children by the subterfuge of issuing thirty to fifty year bonds is nothing short of cowardly, if not indeed dishonest. We need, as never before, the services of highway engineers thoroughly trained in both theory and practice. Only such can show us the wisest way in which to spend the vast sums devoted to pavement and highway construction.

While progress has been made, it seems to the writer that the most important problems of road construction still remain to be solved. It has seemed to the writer that real progress would be made by breaking away entirely from the present temporary construction on main trunk highways, as involving an unreasonable annual cost. We are now past the stage where we can see but one best way of constructing a road. We recognize that the selection of road material and the method of incorporation into a road is in large part a local question, in fact that highway construction obeys the same rules as do all other forms of good engineering. It would seem certain that the happy union of theory with practice of road construction provided in the Columbia graduate course will result in well trained and well balanced highway engineers. Such will find a free field with great opportunities for usefulness.

REPORT OF THE COMMITTEE ON THE TEACHING OF MATHEMATICS TO STUDENTS OF ENGINEERING.

To the Society for the Promotion of Engineering Education:

The committee was appointed at a joint meeting of mathematicians and engineers held in Chicago, December 30–31, 1907, under the auspices of the Chicago Section of the American Mathematical Society, and Sections A and D of the American Association for the Advancement of Science,* and on the suggestion of officers of the Society for the Promotion of Engineering Education who were there present, the committee was instructed to report to this Society.

The membership of the committee is as follows:

ALGER, Philip R., professor of mathematics, U. S. Navy, Annapolis, Md.

CAMPBELL, Donald F., professor of mathematics, Armour Institute of Technology, Chicago, Ill.

ENGLER, Edmund A., president of the Worcester Polytechnic Institute, Worcester, Mass.

HASKINS, Charles N., assistant professor of mathematics, Dartmouth College, Hanover, N. H.

HOWE, Charles S., president, Case School of Applied Science, Cleveland, Ohio.

KUICHLING, Emil, consulting civil engineer, New York City.

MAGRUDER, William T., professor of mechanical engineering, Ohio State University, Columbus, Ohio.

MODJESKI, Ralph, civil engineer, Chicago, Ill.

OSGOOD, William F., professor of mathematics, Harvard University, Cambridge, Mass.

SLICHTER, Charles S., consulting engineer of the U. S. Reclamation Service, professor of applied mathematics, University of Wisconsin, Madison, Wis.

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* For an account of the Chicago meeting, see *Science* for 1908 (July 12, 24, and 31; August 7 and 28; and September 4).

STEINMETZ, Charles P., consulting engineer of the General Electric Company, professor of electrical engineering, Union University, Schenectady, N. Y.

SWAIN, George F., consulting engineer, professor of civil engineering, Harvard University, Cambridge, Mass.

TOWNSEND, Edgar J., dean of the College of Science and professor of mathematics, University of Illinois, Urbana, Ill.

TURNEAURE, Frederick E., dean of the College of Mechanics and Engineering, University of Wisconsin, Madison, Wis.

WALDO, Clarence A., head professor of mathematics, Washington University, St. Louis, Mo.

WILLIAMS, Gardner S., consulting engineer, professor of civil, hydraulic and sanitary engineering, University of Michigan, Ann Arbor, Mich.

WOODWARD, Calvin M., dean of the School of Engineering and Architecture and professor of mathematics and applied mechanics, Washington University, St. Louis, Mo.

WOODWARD, Robert S., president of the Carnegie Institution of Washington, Washington, D. C.

ZIWET, Alexander, professor of mathematics, University of Michigan, Ann Arbor, Mich.

HUNTINGTON, Edward V., chairman, assistant professor of mathematics, Harvard University, Cambridge, Mass.

After deliberation, the committee decided that it could best carry out the purpose for which it was appointed by preparing *a synopsis of those fundamental principles and methods of mathematics which, in the opinion of the committee, should constitute the minimum mathematical equipment of the student of engineering,* and the chairman was instructed to submit for discussion a preliminary draft of such a synopsis. In order to secure as wide a discussion as possible, the committee voted to accept the invitation of the Society for the Promotion of Engineering Education to publish this preliminary draft in the *Bulletin* in advance of its presentation to the Society, and to solicit criticisms and suggestions from all members of the Society, whether members of the committee or not.

It should be distinctly understood that this advance publication is merely a tentative draft, prepared by the chairman, and still under discussion by the members of the committee; *the committee as a whole is not to be held responsible for any part of the synopsis in its present form.*

The synopsis, as now planned, will consist of six parts:

1. A Syllabus of Elementary Algebra;
2. A Syllabus of Plane Trigonometry;
3. A Syllabus of Differential and Integral Calculus;
4. Numerical Computation and the Solution of Equations;
5. Geometry (Elementary and Analytical);
6. A Syllabus of Elementary Dynamics;

preceded by the following introductory note, explaining its scope and purpose:

"It is hoped that this report may be serviceable in two ways: first, to the teacher, as an indication of where the emphasis should be laid; and secondly, to the student, as a syllabus of facts and methods which are to be his working tools. It does not include data for which the student would properly refer to an engineers' hand-book; it includes rather just those things for which he ought never to be obliged to refer to any book—the things which he should have constantly at his fingers' ends.

"The teacher of mathematics should see to it that at least these facts are perfectly familiar to all his students, so that the professor of engineering may presuppose, with confidence, at least this much mathematical knowledge on the part of his students. On the other hand, if the professor of engineering needs to use, at any point, more advanced mathematical methods than those here mentioned, he should be careful to explain them to his class.

"The committee has not found it possible to propose a detailed course of study. The order in which these topics should be taken up must be left largely to the discretion of the individual teacher. The committee is firmly of the opinion, however, that whatever order is adopted, the principal part of the course should be *problems worked by the students,* and that all these problems should be *solved on the basis of a* *small number of fundamental principles and methods, such as are here suggested.*

"The defects in the mathematical training of the student of engineering appear to be largely in knowledge and grasp of fundamental principles, and the constant effort of the teacher should be to ground the student thoroughly in these fundamentals, which are too often lost sight of in a mass of details.

"A pressing need at the present time is a series of synoptical text-books, which shall present, (1) the fundamental principles of the science in compact form, and (2) a classified and graded collection of problems (which would naturally be subject to continual change and expansion). It is the hope of the committee that this report, which is confined to the first part of the desired text-book, will stimulate throughout the country practical contributions toward the second."

In the early part of its investigation the committee collected a large amount of information in regard to the present status of mathematical instruction for engineering students. Since that time, however, a much more inclusive inquiry has been undertaken by the International Commission on the Teaching of Mathematics, of which the American Commissioners are Professors D. E. Smith, J. W. A. Young and W. F. Osgood. In order to avoid unnecessary duplication, this committee voted to turn over all the results of its own inquiry in this field to the larger commission, to be worked up in accordance with the general scheme adopted by that commission, and to be incorporated in their report. This material is therefore not included in the present report.

Respectfully submitted,
EDWARD V. HUNTINGTON,
Chairman.

June, 1911.

A SYLLABUS OF THE FORMAL PART OF ELEMENTARY ALGEBRA.

This syllabus is intended to include those facts and methods of elementary algebra which a student who has completed a course in that subject should be expected to "know by heart"—that is, those fundamental principles which he ought to have made so completely a permanent part of his mental equipment that he will never need to "look them up in a book."

It is not intended as a program of study for beginners, and no attempt has been made to arrange the topics in the order in which they should be taught. In reviewing the subject, however, either at the end of the course in algebra, or at the beginning of any later course, such a syllabus will be found serviceable to both teacher and student; and in the hands of a skillful teacher, and supplemented by an adequate collection of problems, it might well be made the basis of a course of study conducted by the "syllabus method."

One of the chief defects in the present-day teaching of algebra is the multiplicity of detached rules with which the student's mind is burdened;* and every successful attempt to knit together a number of these detached rules into a single general principle (provided this principle is simple and easily applied) should conduce to economy of mental effort, and diminish the liability to error.

TABLE OF CONTENTS.

CHAPTER I. TRANSFORMATION OF ALGEBRAIC EXPRESSIONS.
- General laws of addition and multiplication.
- Type-forms of multiplication (Factoring).
- Fractions.
- Negatives.
- Radicals and Imaginaries.
- Exponents and Logarithms.

CHAPTER II. SOLUTION OF EQUATIONS.
- Legitimate operations on equations.
- To solve a single equation.
  - Quadratic equations.
  - Exponential equations.
- To solve a set of simultaneous equations.

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* For example, in a recent prominent text-book there are no less than *fifty* italicized rules in the part of the book preceding quadratic equations!

CHAPTER III. MISCELLANEOUS TOPICS.
- Ratio and proportion.
- Variation.
- Inequalities.
- Arithmetical, geometric, and harmonic progressions.

CHAPTER I.

TRANSFORMATION OF ALGEBRAIC EXPRESSIONS.

1. The ordinary operations of transforming and simplifying algebraic expressions should be so familiar to the student that he performs them almost instinctively; at the same time he should be able, whenever called upon, to justify each step of his work by reference to some one or more of a small number of well established principles.

For example, if the student is asked *by what authority* he replaces $\frac{a+x}{b+x}$ by $\frac{a}{b}$, or $\sqrt{a^2+b^2}$ by $a+b$ (to mention only two of the commonest blunders), he will be forced to recognize either that he is making use of methods that he has never proved, and that are in fact erroneous, or else (which is more likely) that he is working altogether in the dark, without any conscious reason for the steps he has taken.

The following list of such principles, while making no pretense at logical completeness, will be sufficient for all practical purposes.

2. General laws of addition and multiplication.

$a+b=b+a.$ $ab=ba.$ (Commutative laws.)

$(a+b)+c=a+(b+c).$ $(ab)c=a(bc).$ (Associative laws.)

$a(b+c)=ab+ac.$ (Distributive law.)

$a+0=a.$ $a\times 1=a.$ $a\times 0=0.$

These laws hold when a, b, c are any of the quantities that occur in ordinary algebra, whether "real" or "complex."* *The student should be constantly encouraged to test general algebraic statements by substituting concrete numerical values.*

3. Type-forms of multiplication (Factoring).

The following type-forms of multiplication are the ones that are most important to remember:

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* This syllabus is confined chiefly to the algebra of real quantities; the algebra of complex quantities will be treated only incidentally.

$$a^2 - b^2 = (a - b)(a + b),$$

$$a^3 - b^3 = (a - b)(a^2 + ab + b^2),$$

and so on; the general case is best remembered in the form

$$1 - x^n = (1 - x)(1 + x + x^2 + x^3 + \cdots + x^{n-1}).$$

Note also that in the algebra of real quantities, $a^n + b^n$ is divisible by $a + b$ when and only when n is *odd*. Thus:

$$a^3 + b^3 = (a + b)(a^2 - ab + b^2).$$

Further: $(x + a)(x + b) = x^2 + (a + b)x + ab,$

and the "binomial theorem":

$$(a + b)^2 = a^2 + 2ab + b^2, \quad (a + b)^3 = a^3 + 3a^2b + 3ab^2 + b^3,$$

$$(a - b)^2 = a^2 - 2ab + b^2, \quad (a - b)^3 = a^3 - 3a^2b + 3ab^2 - b^3;$$

$$(a + b)^n =$$

$$a^n + na^{n-1}b + \frac{n(n-1)}{2\,!}a^{n-2}b^2 + \frac{n(n-1)(n-2)}{3\,!}a^{n-3}b^3 + \cdots$$

$$\cdots + \frac{n(n-1)(n-2)}{3\,!}a^3b^{n-3} + \frac{n(n-1)}{2\,!}a^2b^{n-2} + nab^{n-1} + b^n,$$

where $k! =$ "k factorial" $= 1 \times 2 \times 3 \times \cdots \times k$.

4. Fractions.

Def. If $bx = a$, then and only then we write $x = \frac{a}{b}$ (or a/b, or $a \div b$).

Here a is called the numerator and b the denominator of the fraction. A fraction with a zero denominator, as $a/0$, does not represent any definite quantity. For, if a is not zero, there is *no* quantity x such that $0 \times x = a$; and if $a = 0$, then *every* quantity x will have this property. Hence, *the denominator of a fraction must always be different from zero.*

From the definition, $a/1 = a$; also

$$\frac{a}{a} = 1, \quad \frac{0}{a} = 0, \qquad (a \neq 0).^*$$

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* The symbol $\neq$ means "not equal to."

To add two fractions with common denominator:

$$\frac{a}{c}+\frac{b}{c}=\frac{a+b}{c}.$$

To multiply two fractions:

$$\frac{a}{b}\times\frac{x}{y}=\frac{ax}{by}.$$

To divide by a fraction, "invert the divisor and multiply":

$$\frac{a}{b}\div\frac{x}{y}=\frac{a}{b}\times\frac{y}{x}=\frac{ay}{bx}.$$

The value of a fraction is not changed if we multiply (or divide) both the numerator and the denominator by any quantity not zero:

$$\frac{a}{b}=\frac{ma}{mb} \qquad (m \neq 0).$$

This is the most important principle concerning fractions.

For example, *to reduce two fractions to a common denominator,* we have merely to multiply numerator and denominator of each fraction by a suitable factor.

Again, *to simplify a complex fraction,* we multiply the whole numerator and the whole denominator by any quantity which will "absorb" all the subsidiary denominators. Thus, by multiplying by xyz, we have

$$\frac{\frac{a}{x}+\frac{b}{y}}{\frac{c+d}{z}}=\frac{ayz+bxz}{(c+d)xy},$$

at once, by a single mental process. (The common practice of reducing the numerator and denominator separately, and then inverting the denominator and multiplying, is tedious and clumsy.)

Def. If $bx=1$, then $x=1/b$, which is called the *reciprocal* of b. To divide by $b\,(b \neq 0)$ is the same as to multiply by the reciprocal of b.

5. Negatives.

Def. If $a+x=0$, then and only then we write $x=-a$. In particular, $-(-a)=a$.

If a is not zero, $-a$ is always *opposite* to a; that is, if a is positive, $-a$ is negative, and if a is negative, $-a$ is positive.

Thus, if $a = -3$, which is a negative quantity, then $-a = 3$, which is positive.

The notation $|a|$, which is coming into use more and more widely, means the *absolute value of a*, that is, the numerical value of a regardless of sign; thus, $|5| = 5$, $|-5| = 5$.

The laws of operation with the minus sign are best remembered by regarding $-a$ as the product of a and -1:

$$(-1) \times a = -a,$$

whence, in particular (putting $a = -1$),

$$(-1) \times (-1) = 1.$$

When this is done, the customary formulas:

$$(-a)(-b) = ab, \quad (-a)(b) = -ab, \quad \frac{-a}{b} = \frac{a}{-b} = -\frac{a}{b}, \quad \frac{-a}{-b} = \frac{a}{b},$$

become immediate consequences of the general laws of multiplication and division, and therefore need not be separately memorized; and the same is true of the formula

$$a - (x + y - z) = a - x - y + z,$$

which, when remembered in the following form, becomes an immediate application of the distributive law: "a minus sign in front of a parenthesis must be 'distributed' through every term within, if the parentheses are to be taken away."

By knitting together in this way the rules for negatives with the general rules of operation, the total number of processes to be remembered and applied, and hence the liability to error, is materially reduced.

Def. If $a + x = b$, then and only then we write $x = b - a$. It is easily shown that $b - a = b + (-a)$; that is, *subtracting any quantity a is the same as adding the opposite of a.*

6. Radicals.

Def. If a is *positive*, and n is any positive integer, there will always be one positive value of x such that $x^n = a$. This value x is denoted by $\sqrt{a}$, and is called the (principal) *nth root of a.*

It should be noticed that while there are (for example) two square roots of 9, namely 3 and -3, it is only the positive one of these two values that is denoted by $\sqrt{9}$; that is, the mark $\sqrt{9}$ means 3 and not -3.

The radical sign, except in the case of square roots, and sometimes in the case of cube roots, should always be replaced by *fractional exponents* (see below) when it is desired to compute with these quantities; this done, no special rules for the manipulation of radicals need then be remembered beyond the general laws of exponents.

Square roots. If a and b are positive,

$$\sqrt{a^2b} = a\sqrt{b}, \quad \text{and} \quad \sqrt{a}\sqrt{b} = \sqrt{ab}.$$

Note also the process called "rationalizing the denominator (or numerator) of a fraction"; for example,

$$\frac{c}{\sqrt{a}+\sqrt{b}} = \frac{c}{\sqrt{a}+\sqrt{b}} \times \frac{\sqrt{a}-\sqrt{b}}{\sqrt{a}-\sqrt{b}} = \frac{c(\sqrt{a}-\sqrt{b})}{a-b};$$

$$\frac{\sqrt{1-x}}{\sqrt{1+x}} = \frac{\sqrt{1-x}}{\sqrt{1+x}} \times \frac{\sqrt{1-x}}{\sqrt{1-x}} = \frac{1-x}{\sqrt{1-x^2}}.$$

Def. If a is *negative*, and n is *odd*, there will always be one negative value of x such that $x^n = a$; this value is denoted by $\sqrt[n]{a}$, and is called the (principal) nth root of a.

Thus $$\sqrt[3]{-8} = -2.$$

7. Imaginaries.

If a is *negative*, and n is *even*, then there is *no* positive or negative nth root of a. Hence, such quantities do not occur in the algebra of positive and negative quantities. They occur only in the more general *algebra of complex quantities;* in this algebra every quantity a (except zero) has n *distinct* n*th roots*, the notation $\sqrt[n]{a}$ being applied, as occasion requires, to any one of these n values. The detailed study of this general algebra is probably too difficult for a first course; for such applications as occur in elementary work, the following working rules are sufficient:

1) In manipulating a complex quantity of the form $\sqrt{-b}$, where b is positive, write $\sqrt{-b} = \sqrt{-1}\sqrt{b} = i\sqrt{b}$, and treat i like any other letter; then simplify the result by the relation $i^2 = -1$.

2) Every complex quantity can be written in the form $a + ib$, where a and b are "real" (that is, positive, negative, or zero); and if $a + ib = a' + ib'$, then $a = a'$ and $b = b'$.

In electrical engineering the letter i is used to denote current, and $\sqrt{-1}$ is denoted by j.

8. Exponents.

The subject of negative and fractional exponents is a part of algebra in which the preparation of the student is apt to be especially unsatisfactory.

Definition of negative and fractional exponents. If a is positive, and p and q are any positive integers, then

$$a^0 = 1, \qquad a^{-p} = \frac{1}{a^p}, \qquad a^{1/q} = \sqrt[q]{a}, \qquad a^{p/q} = \sqrt[q]{a^p}.$$

9. Laws of operation with exponents.

If a and b are positive, then:

$$a^{m+n} = a^m a^n, \quad a^{mn} = (a^m)^n, \quad (ab)^m = a^m b^m,$$

$$a^0 = 1, \qquad a^{-m} = \frac{1}{a^m}, \qquad a^{1/m} = \sqrt[m]{a}.$$

All these laws hold for any values of m and n; the three fundamental ones can readily be recalled to mind through simple special cases, such as a^3a^2, $(a^3)^2$, and $(ab)^3$.

The three other laws commonly mentioned, namely

$$a^{m-n} = a^m/a^n, \quad a^{m/n} = \sqrt[n]{a^m}, \quad (a/b)^m = a^m/b^m,$$

are immediate corollaries of those just mentioned.

If a is *negative*, and m not an integer, a^m will, in general, be a complex quantity. In such cases, let $a' = -a$, so that a' is positive, and write $a^m = (-1)^m a'^m$, where $(-1)^m$ must then be handled according to the rules of operation in the algebra of complex quantities.

10. Logarithms.

The subject of logarithms should be taught in logical connection with the subject of exponents. The common practice of separating these subjects, and treating logarithms as a part of trigonometry, is unfortunate. Numerous applications of logarithms can be found that have nothing to do with trigonometry; moreover, the training in the use of logarithms which a student gets in trigonometry is usually quite inadequate as a preparation for the applications of logarithms in any of his later work outside of surveying.

Def. The *logarithm* of a (positive) number, to any (positive) base, is the *exponent* of the power to which the base must be raised to produce that number.

Thus, the notation

$$x = \log_b N$$

means

$$b^x = N.$$

Note that negative numbers in general have no logarithms in the algebra of real quantities.

From the laws of exponents we have, whatever the base may be:

$$\log (ab) = \log a + \log b, \quad \log \left(\frac{a}{b}\right) = \log a - \log b,$$

$$\log (a^n) = n \log a, \qquad \log \sqrt[n]{a} = \frac{1}{n} \log a,$$

$$\log 1 = 0, \quad \log (base) = 1.$$

Only two bases are in common use. For purposes of numerical computation, the base chosen is 10, and in this system

$$\log (10^n) = n.$$

(See chapter on numerical computation.) In higher mathematics, the base $e = 2.718 \cdots$ is used, for the reason that the use of this base simplifies certain formulas in the calculus; in this system $\log (e^n) = n$.

Change of base. To find $\log_e N$ when $\log_{10} N$ is known, let $x = \log_e N$, that is, $e^x = N$. Then take the logarithm of both sides of this equation to base 10, and solve for x.

The resulting formula, $\log_e N = (\log_{10} N)/(\log_{10} e)$, is so easily obtained in this way that it is not worth while to remember it separately. The approximate values

$$\log_{10} e = .4343, \quad \text{and} \quad \log_e N = (2.3026) \log_{10} N,$$

however, are useful to remember.

CHAPTER II.

SOLUTION OF EQUATIONS.

11. Legitimate operations on equations. If a given equation is true, it will still be true if we

(*a*) *add* any quantity we please to both sides;

(*b*) *subtract* any quantity we please from both sides;

(*c*) *multiply* both sides by any quantity we please;

(*d*) *divide* both sides by any quantity we please *except zero;*

(*e*) raise both sides to any *positive integral power;*

(*f*) *extract any *positive integral root* of both sides, except that if an *even* root is extracted, the double sign ± must be used;

(*g*) *take the *logarithm* of both sides (provided both sides are positive).

In regard to (*d*), we must never divide both sides by an unknown quantity without first excluding the possibility that that quantity is zero.

In (*f*), the restriction stated means, for example, that from $A^2 = B$ we can infer merely that $A = \pm \sqrt{B}$; that is, that *either* $A = \sqrt{B}$, or $A = -\sqrt{B}$; but we cannot tell which.

12. To solve a single equation in x, means to find all the values of x that satisfy the equation, or to show that none such exist.

Any value of x that satisfies the equation is called a *root* of the equation.

In testing a root, the only safe method is to substitute the given value in each side of the equation separately, and see whether the results, when reduced, are equal. Thus, we should find that $x = -2$ is a root of the equation $x = 2 - \sqrt{12 - 2x}$, and that $x = 4$ is not a root.

In this connection it should be noticed that if we square both sides of a given equation, the new equation will, in general, have more roots than the given equation. Thus (to use the same example), by squaring $x - 2 = -\sqrt{12 - 2x}$ we have $x^2 - 2x - 8 = 0$. This equation has of course the root -2, since $x = -2$ satisfies the original equation from which this was derived; but it has also the root 4, which was not a root of the original equation.

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* In the algebra of complex quantities (*f*) and (*g*) are not applicable.

The formal process usually called "solving the equation" means merely transforming the equation, by a judicious choice of the legitimate operations, into a form in which the solutions are obvious.

If this is not possible, we must have recourse to the *method of trial and error* which, while often laborious, is always applicable in numerical cases. (See chapter on numerical computation.)

If an equation is given in the factored form:

$$(x-\alpha)(x-\beta)(x-\gamma)\cdots=0,$$

then the roots are obviously $x=\alpha$, $x=\beta$, $x=\gamma,\cdots$. Thus, the roots of $x(x+2)=0$ are 0 and -2.

13. Quadratic equations. To solve the quadratic equation

$$ax^2+bx+c=0,$$

we may divide through by a:

$$x^2+\frac{b}{a}x \qquad = \qquad -\frac{c}{a}$$

and then "complete the square":

$$x^2+\frac{b}{a}x+\left(\frac{b}{2a}\right)^2=\frac{b^2}{4a^2}-\frac{c}{a}=\frac{b^2-4ac}{4a^2};$$

whence,

$$x=\frac{-b\pm\sqrt{b^2-4ac}}{2a};$$

or, we may use the general result just obtained as a formula.

The quantity which must be added to both sides in "completing the square" is obvious by analogy with $x^2+2mx+m^2$, so that this method requires less effort of the memory than the method of solution by formula.

The "method of factoring" is very convenient in certain special cases, when the factors can be obtained by inspection.

The method still sometimes used, of first multiplying through by $4a$ to avoid fractions, is apt to lead to confusion, and should be discouraged.

From the formula it is evident that the *sum of the roots* is

$x_1 + x_2 = -b/a$, and the *product of the roots* is $x_1x_2 = c/a$; also, if the coefficients, a, b, c, are real, the roots will be real-and-distinct, real-and-coincident, or imaginary, according as $b^2 - 4ac$ is positive, zero, or negative.

14. Exponential equations. To solve an equation of the form $a^x = b$, when a and b are positive, *take the logarithm of both sides:* $x \log a = \log b$; and then solve for x.

15. To solve a set of simultaneous equation in x, y, z $\cdots$ means to find all the *sets of values* of $x, y, z, \cdots$, that satisfy all the equations at once, or show that none such exist.

Two simultaneous equations of the first degree, as $ax + by = c$ and $Ax + By = C$, can always be solved in a couple of lines, if the work is arranged as follows:

$$\begin{array}{r|r|r}
7x - 6y = 1 & -5 & -2 \\
14x - 10y = 3 & 3 & 1 \\
\hline
(-35 + 42)x = -5 + 9 & & \\
(12 - 10)y = -2 + 3 & &
\end{array}$$

whence the values of x and y are obvious, provided $aB - bA$ *is not zero.* (If $aB - bA = 0$, there is either no pair of values x, y that satisfies both the equations, or else there are an infinite number of pairs of values that do so; in this latter case, the equations are not independent, that is, either of them can be derived from the other.)

The theory of simultaneous equations, and sometimes the numerical computation, is facilitated by the use of determinants.

In general, n independent equations will suffice to determine n unknown quantities.

CHAPTER III.

MISCELLANEOUS TOPICS.

16. Ratio and Proportion. The "ratio of a to b" means simply the fraction a/b; and a "proportion" is simply an equation between two ratios.

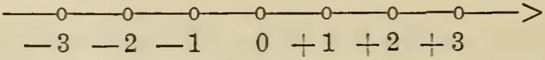
The notation $a:b::c:d$ should be replaced by the equation $a/b=c/d$; and all special terminology, such as "taking a proportion by alternation," "by composition," etc., should be dropped in favor of the ordinary language of the equation.

17. Variation. The statement "y varies as x," or "y varies directly as x," or "y is proportional to x," means $y=kx$, where k is some constant. Similarly, "y varies inversely as x," means $y=k/x$; "y varies inversely as the square of x," means $y=k/x^2$. The constant k can always be determined if we know any pair of values of x and y that belong together.

The statement "y varies as u *and* v," means y varies as the *product* of u and v, that is, $y=kuv$.

18. Inequalities. The notions of "greater and less" are thoroughly familiar when we are dealing only with positive quantities, but the extension of these terms to the algebra of all real quantities (positive, negative, and zero) is apt to cause some confusion.

(a) All *real* quantities (positive, negative, and zero) may be represented by the points of a directed line (running, say, from left to right):



and the notation $a<b$ (read: "a algebraically less than b") means simply that a *precedes* b, or a lies on the left of b, along this line.

Similarly, $a>b$ (read: "a algebraically greater than b") means that a *comes after* b, or lies on the right of b, along the line. (The idea that a negative quantity is a magnitude whose *size* is in some way "less than nothing" should be carefully avoided.)

Obviously, if a and b are any real quantities, one and only one of the three relations: $a = b$, $a < b$, and $a > b$, will hold between them; further, if $a < b$ and $b < c$, then $a < c$.

(b) *Complex* quantities require for their representation the points of a plane instead of the points of a line, and the symbols $<$ and $>$ are not used in connection with these quantities.

Legitimate operations on inequalities. If a given inequality is true, it will still be true if we

(a) *add* any quantity we please to both sides;

(b) *subtract* any quantity we please from both sides;

(c) *multiply* both sides by any *positive* quantity;

(d) *divide* both sides by any *positive* quantity;

(e) raise both sides to any *positive power* (integral or fractional), *provided both sides are positive.*

(f) take the *logarithm* of both sides, *provided both sides are positive.*

If we multiply or divide both sides by any *negative* number, we must *reverse the sense of the inequality.*

The neglect of the rules for handling inequalities is the source of many common errors.

19. Arithmetical Progression.

In an arithmetical progression:

$$a, \quad a + d, \quad a + 2d, \quad a + 3d, \quad \cdots,$$

each term is obtained from the preceding by *adding* a constant quantity.

The nth term is obviously $l = a + (n - 1)d$.

The sum of n terms is $S = \dfrac{a + l}{2} n$.

This formula is most easily remembered in the form:

$S =$ (average of the first and last terms) × (number of terms).

The *arithmetic mean* between a and b is $A = \frac{1}{2}(a + b)$.

20. Geometric Progression.

In a geometric progression:

$$a, \quad ar, \quad ar^2, \quad ar^3, \quad \cdots,$$

each term is obtained from the preceding by *multiplying* by a constant quantity.

The nth term is obviously $l = ar^{n-1}$.

The sum of n terms is $S = \dfrac{a(1-r^n)}{1-r}$.

This formula is best remembered in connection with the rule for factoring:

$$1 - r^n = (1-r)(1 + r + r^2 + r^3 + \cdots + r^{n-1}).$$

The *geometric mean* between a and b is $G = \sqrt{ab}$.

The geometric mean is also called the *mean proportional.*

Infinite geometric progression. If $|r| < 1$, the sum of n terms approaches the limit

$$\frac{a}{1-r}$$

as n increases indefinitely (since, in the expression for S, if $|r| < 1$, r^n approaches zero).

21. Harmonic Progression.

A harmonic progression is a series of terms whose reciprocals are in arithmetical progression. (The harmonic progression is not of great importance.)

The *harmonic mean* between a and b is $H = \dfrac{2ab}{a+b}$.

A SYLLABUS OF ELEMENTARY GEOMETRY AND MENSURATION.

This syllabus is intended to include those facts and methods of elementary geometry which a student should have so firmly fixed in his memory that he will never think of looking them up in a book.

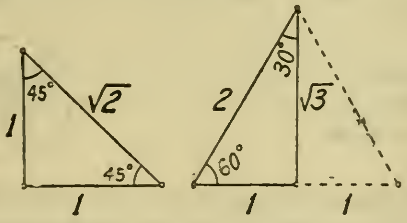
1. Right Triangles.

In a right triangle, the square on the hypotenuse is equal to the sum of the squares on the other two sides (Pythagoras, 580–501 B.C.); and the sum of the acute angles is 90°.

Examples of right triangles with integral sides: 3, 4, 5; 5, 12, 13.

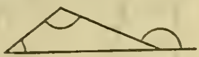
Two right triangles are congruent when they agree with respect to (*a*) any side and an acute angle; or (*b*) any two sides.

In the "45° triangle" and the "30–60° triangle," the ratios of the sides are as indicated in the figure.



2. Oblique Triangles.

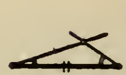
In any plane triangle, the sum of the angles is 180°. Hence, an exterior angle of a triangle equals the sum of the opposite interior angles.



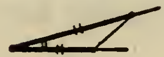
Of two unequal sides in a triangle, the greater is opposite the greater angle.

A plane triangle is, in general, wholly determined when any three of its parts (not all angles) are given.

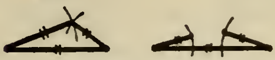
There are four cases:



(*a*) two angles (provided their sum is less than 180°) and one side;

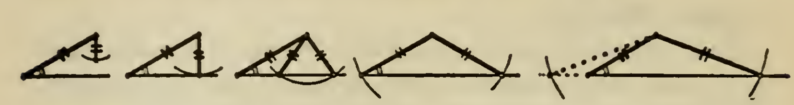


(*b*) two sides and the included angle;



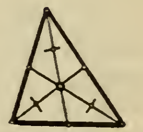
(*c*) the three sides (provided the largest is less than the sum of the other two);

(*d*) two sides and the angle opposite one of them (the "ambiguous case," in which we may have two solutions, or one, or none).



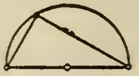
Hence the usual rules for testing the equality of two plane triangles.

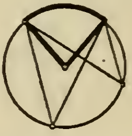
The center of gravity of a plane triangle is the intersection of the three medians, and is two thirds of the way from any vertex to the middle point of the opposite side.



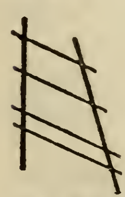
3. Angles in a Circle.

An angle inscribed in a semicircle is a right angle.





An angle subtended by an arc of a circle at any point of the circumference is equal to half the angle subtended by the same arc at the center.



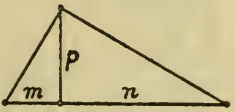
4. Similar Figures. Proportion.

If any two lines are cut by a set of parallels, the corresponding segments are proportional. (Hence the usual rule for dividing a given line into any number of equal parts.)

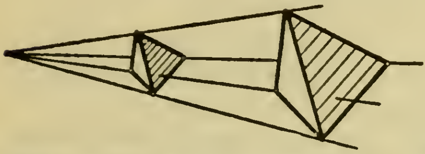
In all problems in proportion, the notation $a:b::c:d$, and all special terminology, such as "taking a proportion by alternation," "by composition," etc., should be abandoned in favor of the ordinary language of the equation. For example, if $a/b = c/d$, then, by adding 1 to both sides, $(a + b)/b = (c + d)/d$; and by subtracting 1 from both sides, $(a - b)/b = (c - d)/d$; etc.

If two plane triangles are similar, their corresponding sides are proportional.

In a right triangle, the perpendicular from the vertex of the right angle to the hypotenuse is a mean proportional between the segments of the hypotenuse:



$$p^2 = mn.$$

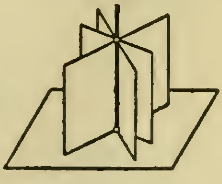


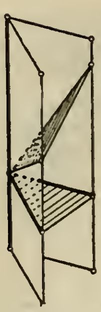
Any two similar figures, in the plane or in space, can be placed in "perspective," that is, so that lines joining corresponding points of the two figures will pass through a common point. In other words, of two similar figures, one is merely an enlargement of the other.

In two similar figures, if k is the factor of proportionality, any *length* in one $= k \times$ (the corresponding *length* in the other); any *area* in one $= k^2 \times$ (the corresponding *area* in the other); any *volume* in one $= k^3 \times$ (the corresponding *volume* in the other).

5. Lines and Planes.

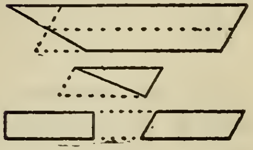
If a line is perpendicular to a plane, every plane containing that line is perpendicular to the plane.





A dihedral angle is measured by a plane angle formed by two lines, one in each face, perpendicular to the edge.

6. Plane Areas.



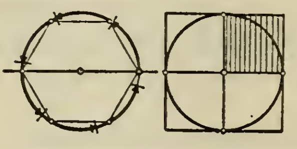
Area of parallelogram
$= \text{base} \times \text{altitude}.$

Area of triangle
$= \frac{1}{2}\ \text{base} \times \text{altitude}.$

Area of trapezoid
$= \frac{1}{2}\ \text{sum of} \parallel \text{sides} \times \text{alt.}$
$= \text{mid-section} \times \text{altitude}.$

7. The Circle.

($\pi = 3.1416 \cdots = 22/7$, approximately.)



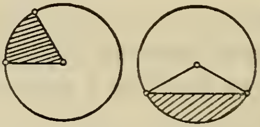
Circumference of circle $= 2\pi r$.

(Proved by regarding the circle as the limit of an inscribed or circumscribed polygon; proof rather long.)

Area of circle $= \pi r^2$.

(Proof by regarding circle as limit of sum of triangles radiating out from the center, the altitude of each triangle being the radius of the circle; hence, area of circle $= \frac{1}{2}$ circumference × radius.)

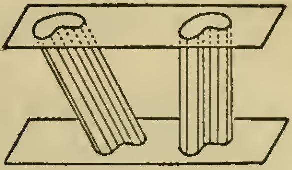
$$\frac{\text{Area of sector}}{\text{area of circle}} = \frac{\text{angle of sector}}{\text{four right angles}}\ ;\ \text{hence,}$$



Area of sector $= \frac{1}{2} r^2 \theta$, where θ is the angle in radians.

For area of segment, subtract triangle from sector.

8. The Cylinder.

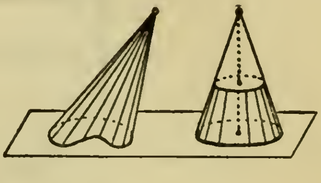


Volume of any cylinder (or prism) = base × altitude.

Area of curved surface of any *right* cylinder (or *right* prism) = perimeter of base × altitude.

(Proof by regarding the area as the limit of a sum of rectangles whose common altitude is the altitude of the cylinder; or, by slitting the cylinder along an "element" and rolling the surface out into a rectangle.)

9. The Cone.



Volume of any cone (or pyramid) = 1/3 base × altitude.

(Proof by dissecting a triangular prism; or, more simply, by the integral calculus.)

Area of curved surface of a *right* circular cone (or a *regular* pyramid) = 1/2 perimeter of base × slant height.

(Proof by regarding the area as the limit of a sum of triangles whose common altitude is the slant height of the cone.)

Area of frustum of a right circular cone (or of a regular pyramid)

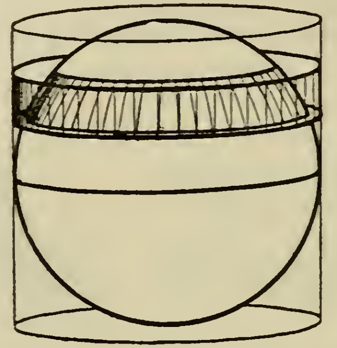
= 1/2 sum of perimeters of bases × slant height.
= perimeter of mid-section × slant height.

(Proof by regarding the area as the limit of the trapezoids whose common altitude is the slant height of the frustum.)

10. The Sphere.

Area of a zone = circumference of great circle × altitude of zone.

In other words, the area of the sphere cut out by two parallel planes is equal to the area of the portion of the circumscribing cylinder intercepted between the same pair of parallel planes. (Proof by regarding the zone as the limit of a sum of conical frustums.) Hence,



Area of sphere $= 4\pi r^2$

$= $ area of four great circles of the sphere.

In other words, the *area of the sphere is equal to the area of the curved surface of the circumscribing cylinder.*

Volume of sphere $= \frac{4}{3}\pi r^3$.

(Proof by regarding sphere as limit of a sum of pyramids radiating out from the center, the altitude of each pyramid being the radius of the sphere; hence, volume of sphere $= \frac{1}{3}$ area of sphere × radius.)

$$\frac{\text{Area of a lune}}{\text{area of sphere}} = \frac{\text{angle of lune}}{\text{four right angles}}.$$

Area of spherical triangle is proportional to its spherical excess (that is, the excess of the sum of its angles over 180°).

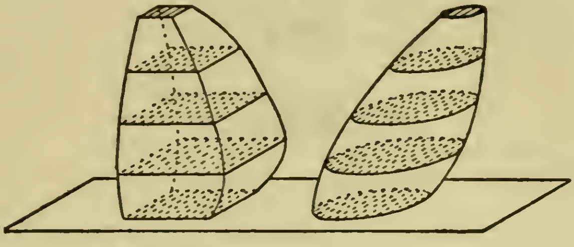
(Proof by considering three lunes which have the given triangle in common.)

The following further theorems, the proof of which involves the integral calculus, are mentioned here also, because they are easy to remember and are often serviceable in elementary work.

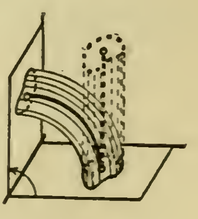
11. Cavalieri's Theorem (1598–1647).

Suppose two solids have their bases in the same plane, and let the sections made in each solid by any plane parallel to the base be called "corresponding sections." If then the corresponding sections of the two solids are always equal, the volumes of the solids will be equal.

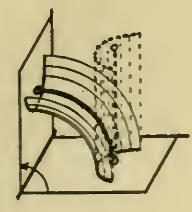
(Proof by regarding each of the solids as the limit of a pile of thin slabs.)



12. Theorems of Guldin (1577–1643), or **of Pappus** (about 290 A.D.).



1. Suppose a plane figure revolves about an axis in its plane but not cutting it. Then the volume of the solid thus generated is equal to the area of the given figure times the length of the path traced by its center of gravity.



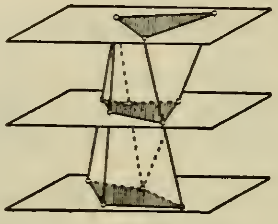
2. Suppose a plane curve revolves about an axis in its plane but not cutting it. Then the area of the surface thus generated is equal to the length of the given curve times the length of the path traced by its center of gravity.

13. The Prismoidal Formula.

The prismoidal formula holds for any solid lying between two parallel planes and such that the area of a section at distance x from the base is expressible as a polynomial of the second (or third) degree in x.

If A, B = areas of the bases, M = area of a plane section midway between the bases, and h = altitude, then

$$\text{Volume of prismoid} = \frac{h}{6}(A + B + 4M).$$



A SYLLABUS OF PLANE TRIGONOMETRY.

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CHAPTER I. SINE, COSINE, AND TANGENT OF ACUTE ANGLES.

Definitions of sine, cosine, and tangent of an acute angle as ratios between the sides of a right triangle:

$$\sin x = \text{opp}/\text{hyp}; \quad \cos x = \text{adj}/\text{hyp}; \quad \tan x = \text{opp}/\text{adj}.$$

To trace the changes in these functions, as the angle changes from 0° to 90° (circle of reference).

Use of tables. Exact values of functions of 30°, 45°, and 60°.

To find remaining functions of an angle when one function is given (draw right triangle). To construct an angle from its tangent.

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To trace the changes in these functions, as the angle changes from 0° to 360° (circle of reference).

Definitions of cotangent, secant, and cosecant:

$$\cot x = 1/\tan x, \quad \sec x = 1/\cos x, \quad \csc x = 1/\sin x.$$

Definitions of versed sine and coversed sine:

$$\text{vers } x = 1 - \cos x, \quad \text{covers } x = 1 - \sin x.$$

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Functions of $(-x)$. Functions of $(x \pm n90°)$, etc.

Functions of the sum and difference of two angles:

$$\sin(x + y) = \sin x \cos y + \cos x \sin y,$$
$$\cos(x + y) = \cos x \cos y - \sin x \sin y.$$

Functions of twice an angle, and of half an angle.

The inverse functions, $\sin^{-1} x$, $\cos^{-1} x$, $\tan^{-1} x$, etc.

Solution of trigonometric equations.

CHAPTER I.

SINE, COSINE, AND TANGENT OF ACUTE ANGLES.

1. *Definition of sine, cosine, and tangent of an acute angle x.*—In any right triangle, if x is one of the acute angles, the sine, cosine and tangent of x are defined as ratios between the sides of the triangle, as follows:

$$\sin x = \frac{\text{side opp.}}{\text{hypot.}} \qquad \cos x = \frac{\text{side adj.}}{\text{hypot.}}$$

$$\tan x = \frac{\text{side opp.}}{\text{side adj.}}$$

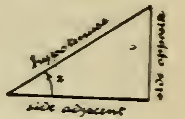


FIG. 1.

These ratios are pure numbers, depending only on the size of the angle.

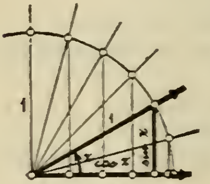


FIG. 2.

2. To trace the changes in these numbers when the angle changes from 0° to 90°, draw the figure so that the denominator of the ratio is kept constant, say equal to 1 inch, and trace the changes in the numerator. Thus, from Fig. 2, when x goes from 0° to 90°, sin x goes from 0 to 1, and cos x goes from 1 to 0; from Fig 3, when x goes from 0° to 90°, tan x goes from 0 to infinity.

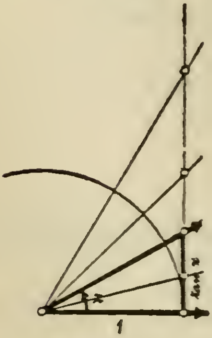


FIG. 3.

3. *Tables.*—The ratios thus defined are called "trigonometric functions" of the angle, and their values have been tabulated, to 4, 5, or 6 places of decimals, in the "tables of trigonometric functions." Before using the printed tables, the student should make his own table, for a few angles, by graphical construction, with a protractor, to two places of decimals.*

* It is clear from the figure that the values of cos x from 0° to 90° are the same as the values of sin x in reverse order; note how this fact is made use of to save space in the tables.

4. The functions of 30°, 45°, and 60° can be found exactly, without the use of the table. Thus, in the triangles which occur in Fig. 4, it is readily proved by the Pythagorean theorem that if the hypotenuse is 1 inch, the shortest side is $\frac{1}{2}$ in., the longest side is $\frac{1}{2}\sqrt{3}$ in., and the middle-sized side $\frac{1}{2}\sqrt{2}$ in. Hence any function of 30°, 45°, or 60° can be read off the figure by inspection. For example,

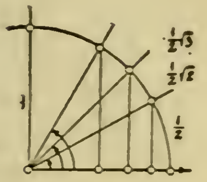


FIG. 4.

$$\sin 30° = \tfrac{1}{2}, \quad \tan 45° = 1, \quad \tan 60° = \sqrt{3}; \quad \text{etc.}$$

5. It is frequently required *to find the remaining functions of an angle when any one function is given.* To do this, draw a right triangle, mark one of the angles, and mark two sides to correspond to the given function. Then compute the remaining side by the Pythagorean theorem, and read off any desired function from the completed figure. For example,

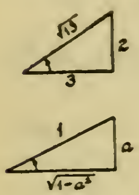


FIG. 5.

Given, $\tan x = \frac{2}{3}$. From the figure, $\sin x = 2/\sqrt{13}$; etc.

Given, $\sin x = a$. From the figure, $\tan x = a/\sqrt{1-a^2}$; etc.

To construct an angle when any one of its functions is given, first find the *tangent* of the angle; when the tangent is known, the construction of the angle is obvious.

6. The notation $\sin^2 x$, etc., is used as an abbreviation for $(\sin x)^2$; etc.

The following fundamental relations are easily proved and remembered from the figure: for any angle x,

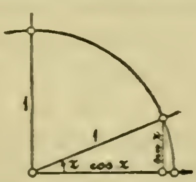


FIG. 7.

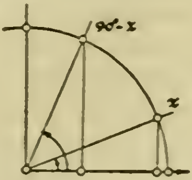


FIG. 8.

$$\sin^2 x + \cos^2 x = 1, \quad \tan x = \frac{\sin x}{\cos x}, \quad \begin{array}{l} \sin(90° - x) = \cos x. \\ \cos(90° - x) = \sin x. \end{array}$$

7. The student should be thoroughly drilled in the definitions of the sine, cosine and tangent, in right triangles in all possible positions in the plane regardless of lettering. Thus, the mental process should be as follows: pointing at the figure, "the tangent of *this* angle is *this* side, divided by *this* side"; etc.

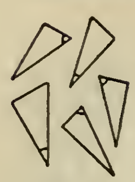


FIG. 9.

The following forms of the original equations are especially useful, and should be emphasized:

side *opp.* = hypot. × *sine*; side *adj.* = hypot. × *cosine.*

SOLUTION OF RIGHT TRIANGLES.

8. We recall that in any right triangle, the sum of the squares on the two legs is equal to the square on the hypotenuse, and the sum of the acute angles is 90°. Hence, when either acute angle is known, the other may be found; and the sine of either acute angle is the cosine of the other:

$$c^2 = a^2 + b^2, \quad \sin A = \cos B.$$

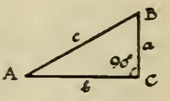


FIG. 10.

9. By the aid of a table of sines, cosines and tangents, *when any two parts of a right triangle, besides the right angle, are given, the remaining parts may be found* (except in the case where the given parts are the two acute angles, in which case the triangle is not determined).

For, we have merely to remember the definitions of the functions, selecting the equations so that only one unknown appears in each equation; then solve for the unknown quantity, and compute by the aid of the tables. The results should be checked by substituting in some relation not used in the direct computation.*

---

* This computation, like many other numerical computations, can often be shortened by the use of the slide rule, or by the use of logarithms; in fact, tables are provided which give the logarithms of the trigonometric functions directly in terms of the angles; but the student should thoroughly understand the use of the functions themselves before he begins to use the logarithmic tables.

10. Numerous problems involving right triangles: isosceles triangles, polygons, oblique triangles solved by means of right triangles, heights and distances, surveying problems, etc.

ORTHOGONAL PROJECTION. COMPONENTS OF FORCES, ETC.

11. The *projection of a length AB* on any line *is the given length times the cosine of the angle* between the lines. (Proof from the definition of cosine.)

The *projection of a plane area* upon any fixed plane is *the given area times the cosine of the angle* between the planes. Proof by the theorem of limits.)

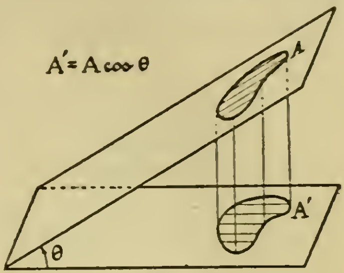
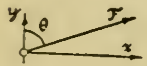


FIG. 11.

12. *The component of a force* along any fixed axis is the *magnitude of the force times the cosine of the angle* between the force and the axis.



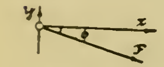


FIG. 12. 13.

Since we usually require the components along two rectangular axes, it is important to remember that $\cos(90° - x) = \sin x$. The mental process should be as follows:

In Fig. 12, the component of F along the y-axis is F times the cosine of θ; the component of F along the x-axis is F times the cosine of the other angle, which is F times the *sine* of θ; that is, $F_y = F\cos\theta$; $F_x = F\sin\theta$. Similarly, in Fig. 13, $F_x = F\cos\phi$; $F_y = -F\sin\phi$ (minus, because it pulls backward along that line).

The components of velocities, accelerations, or any other vector quantities are to be handled in the same way.

13. Every problem should be accompanied by a *sketch* or *diagram*, to show that the student understands the meaning of each step of his work. And in many cases, an accurate graphical solution on a drawing board may be used as a valuable check on the correctness of the numerical computation.

14. Note. *That portion of trigonometry which has been outlined up to this point is so elementary in character, and so readily understood and appreciated by the student, that it may well be introduced much earlier in the course than is usually done—perhaps even as early as the elementary course in plane geometry.*

CHAPTER II.

THE TRIGONOMETRIC FUNCTIONS OF ANY ANGLE.

15. *Angles in general.*—An angle, as the term is used in applied mathematics, is the amount of rotation of a moving radius *OP* about a fixed point *O,* measured from a fixed line

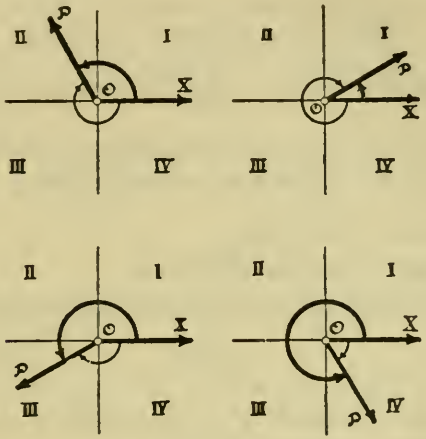


FIG. 14.

OX. Here *OX* is called the *initial line* and *OP* the *terminal line* of the angle. Counterclockwise rotation is positive, and angles are added and subtracted as algebraic quantities. The quadrants are numbered as in the figure; an "angle in quadrant *II*" for example, means an angle whose terminal line lies in quadrant *II.*

16. *Congruent angles* are angles differing by any multiple of 360°.

17. *Complementary angles* are angles whose sum is 90°; *supplementary angles* are angles whose sum is 180°.

18. Units of angular measurement are: the *degree,* subdivided into minutes and seconds, or decimally; the *grade,*

subdivided decimally; and the *radian*, subdivided decimally.

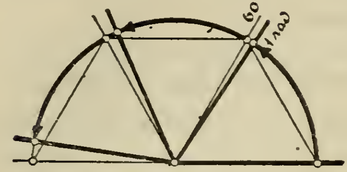


Fig. 15.

1 degree = 1° = 1/90th of a right angle;

1 grade = 1/100th of a right angle (used in France);

1 radian = angle subtended by an arc equal to the radius.

Since ratio of semi-circumference to radius $= \pi$ (where $\pi = 3.1416 \cdots = 3\frac{1}{7}$ approximately), we have

$$\pi \text{ radians} = 180°, \text{ and hence } 1 \text{ radian} = \text{about } 57.3°.$$

19. The *radian* is especially important in problems concerning the motion of a particle in a circular path. Thus, if

r ft. = radius of the circle,
s ft. = length of arc traversed, and
θ radians = angle swept over by the moving radius, then

$$s = r\theta.$$

This important equation is not true unless the angle is measured in radians. Again, if
v ft. per sec. = linear velocity of the particle in its path, and
ω radians per sec. = its angular velocity, then

$$v = r\omega.$$

Further, if the angular velocity $= \omega$ radians per sec. $= N$ rev. per min., then the relation between the numbers ω and N is given by

$$\omega = \frac{\pi N}{30}.$$

In all higher mathematics, when a letter is used for an angle, without designating the unit, it is understood that the letter means the number of radians in the angle.

20. *Definition of sine, cosine, and tangent of any angle.*— Let x be any angle, swept over by a moving radius revolving from OX to OL, and suppose for convenience of language that OX extends horizontally to the right. Assume, for the moment that OX and OL are not perpendicular. From any point P of the moving radius drop a perpendicular on the initial line (or the initial line produced), thus forming a right triangle, called the *triangle of reference* for the given angle x. In this triangle, the perpendicular MP is called the *side opposite O,* and is positive if it runs up, negative if it runs down; the base OM is called the *side adjacent* to O, and is positive if it runs to the right, negative if it runs to the left, and the radius OP is called the *hypotenuse* of the triangle and may always be taken as positive. The *sine, cosine* and *tangent* of the angle x are then defined as follows:

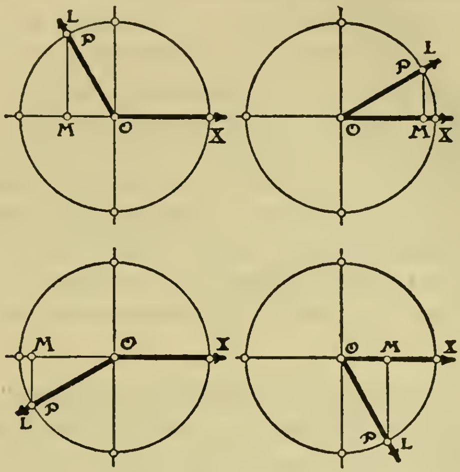


FIG. 16.

$$\sin x = \frac{\text{side opp.}}{\text{hypot.}}, \quad \cos x = \frac{\text{side adj.}}{\text{hypot.}}, \quad \tan x = \frac{\text{side opp.}}{\text{side adj.}} = \frac{\sin x}{\cos x}$$

These ratios are positive or negative numbers, depending only on the position of the terminal side of the angle x, and are called trigonometric functions of x. The functions of any angle congruent to x are the same as the functions of x, so that we need consider only the angles in "the first revolution," that is, angles between 0° and 360°.

21. To trace the changes in each function as the angle changes from 0° to 360°, draw the figure so that the denominator of the ratio is kept constant, say equal to 1 inch, and trace the changes in the numerator (Fig. 17 for the sine and cosine; Fig. 18 for the tangent). Obviously, the sine will be positive for angles in the upper quadrants; the cosine will be positive for angles in the right hand quadrants; and the tangent will be positive in quadrants *I* and *III*.

The definitions of the functions of 0°, 90°, 180°, and 270°, which were not included above, can now be readily obtained by noting what becomes of the function of a variable angle x when x approaches one of these values as a limit.

In using the "circle of reference" be careful to have every angle start from the initial line that extends horizontally to the right.

OTHER TRIGONOMETRIC FUNCTIONS.

22. *Definition of other trigonometric functions.*—Besides the sine, cosine, and tangent, other functions in common use are the *cotangent,* the *secant,* and the *cosecant,* which are most conveniently defined thus:

$$\cot x = \frac{1}{\tan x}, \quad \sec x = \frac{1}{\cos x}, \quad \csc x = \frac{1}{\sin x}.$$

Less important, but often convenient, are the *versed sine* and the *coversed sine:*

$$\operatorname{vers} x = 1 - \cos x, \quad \operatorname{covers} x = 1 - \sin x.$$

23. It is worth remembering that the sine and cosine are always less than (or equal to) 1, in absolute value; their reciprocals, the secant and cosecant, are always greater than (or equal to) 1, in absolute value; the tangent and cotangent may have any value, positive or negative; while the versed sine and coversed sine are always positive, ranging from 0 to 2.

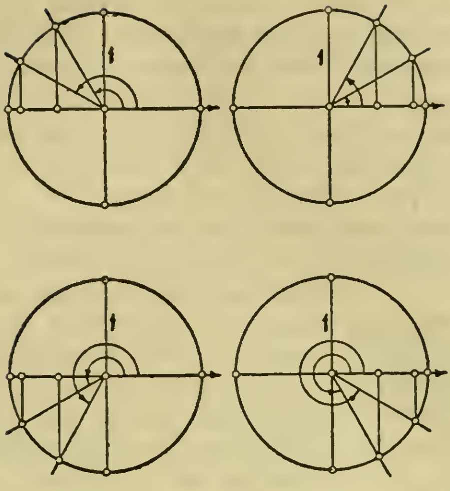


Fig. 17.

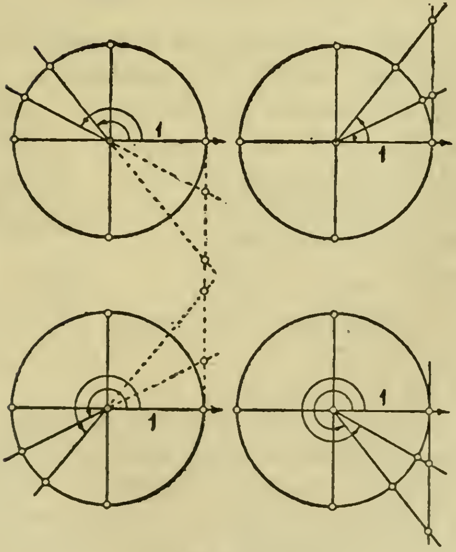


Fig. 18.

24. *Use of the tables: reduction to the first quadrant.*—The tables in common use give the values of the functions only for angles between 0° and 90°, that is, only for angles in the first quadrant. To find the functions of an angle x in one of the other quadrants, find first the "reduced angle" in quadrant *I* (that is, $x - 90°$, or $x - 180°$, or $x - 270°$), and then proceed as in the following examples:*

(*a*) To find $\cos x$, when x is in quadrant *II*. Draw any angle in quadrant *II* to represent the angle x (avoiding, however, lines near the middle of the quadrant) and draw the "reduced angle" $x - 90°$ in quadrant *I*. Then, pointing at the figure, $\cos x$ is *this* line (∿) [divided by the radius], which is the same in length as *this* line (≷) [divided by the radius], which is the *sine* of $x - 90°$; but the first line is negative; hence

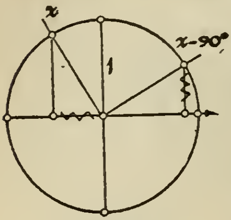


FIG. 19.

$$\cos x = -\sin (x - 90°),$$

where $\sin (x - 90°)$, of course, can be found in the table.

(*b*) To find $\tan x$, when x is in quadrant *II*. Pointing at the figure, $\tan x$ is this line (≷) divided by this line (|||), which is the same as this line (∿) divided by this line (≡), which is the cotangent of $(x - 90°)$; but the signs are unlike; hence

$$\tan x = -\cot (x - 90°),$$

where $\cot (x - 90°)$ can be found from the table.

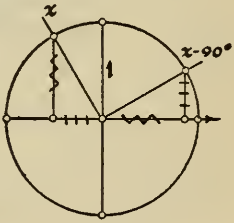


FIG. 20.

Similarly for any other case.

25. The converse problem of finding the angle corresponding to any given function is complicated by the fact that there will be (in general) *two* angles between 0° and 360° corresponding to any given function. The most satisfactory way

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* The given angle is supposed to be already reduced to an angle between 0° and 360°.

to find these two angles, in any numerical case, is to draw the figure, and proceed as in the examples below, in which x_0 in each case represents an angle in the first quadrant which can be found in the table.

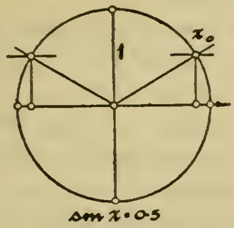


FIG. 21.

Given $\sin x = 0.5$;
$x = x_0$ or $180° - x_0$.

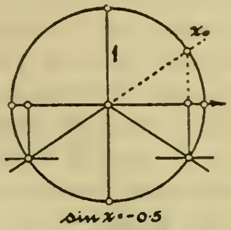


FIG. 22.

Given $\sin x = -0.5$;
$x = 180° + x_0$ or $360° - x_0$.

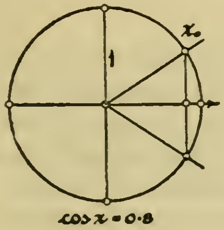


FIG. 23.

Given $\cos x = 0.8$;
$x = x_0$ or $360° - x_0$.

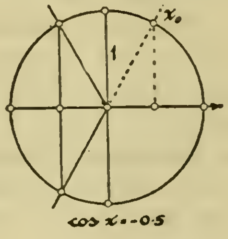


FIG. 24.

Given $\cos x = -0.5$;
$x = 180° - x_0$ or $180° + x_0$.

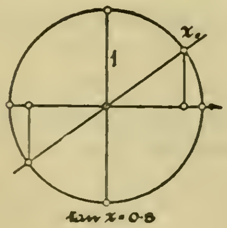


FIG. 25.

Given $\tan x = 0.8$;
$x = x_0$ or $180° + x_0$.

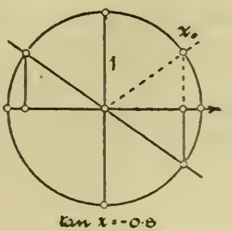


FIG. 26.

Given $\tan x = -0.8$;
$x = 180° - x_0$ or $360° - x_0$.

These results are not formulæ to be memorized; it is much safer, and more intelligent, to draw the appropriate figure, or to visualize it in the mind, for each case as it arises. The student should be thoroughly drilled in numerical cases, especially for angles in the second quadrant.

Notice that an angle is completely determined when we know the value of any one of its functions, and the *sign* of any other function (not the reciprocal of the first).

It we restrict ourselves to angles between 0° and 180°, as in the case of angles in a triangle, then an angle is wholly determined by either its cosine or its tangent; but there will be two angles, x and $180° - x$, corresponding to a given sine.

26. The functions of certain angles in the later quadrants, corresponding to 30°, 45°, and 60° in quadrant *I*, may be found exactly, without the use of the tables, by inspection of the figure (see § 4).

For example, $\cos 120° = -\frac{1}{2}$.

27. If it is required to find the remaining functions of an angle when one function is given, draw a right triangle and proceed as in § 5, considering only the absolute values of the quantities, without regard to sign; then adjust the sign of the answer according to the quadrant in which the angle lies. Or, the angle may be drawn at once in the proper quadrant.

SOLUTION OF OBLIQUE TRIANGLES.

28. In any plane triangle the following theorems are easily proved from a figure:

(1) *The "Law of Sines."*—Any side is to any other side as the sine of the angle opposite the first side is to the sine of the angle opposite the other side; in the usual notation:

$$\frac{a}{b} = \frac{\sin A}{\sin B},$$

with two analogous formulæ obtained by "advancing the letters."

(2) *The "Law of Cosines."*—The square of any side is equal to the sum of the squares of the other two sides, minus twice their product times the cosine of the included angle:

$$a^2 = b^2 + c^2 - 2bc \cos A,$$

with two analogous formulæ obtained by "advancing the letters."

These two laws, with the fact that the sum of the angles is 180°, suffice to "solve" any plane triangle, and are important in many theoretical considerations.

The following formulæ which are especially adapted to logarithmic computation, give the tangents of the half-angles in terms of the sides, and are included here for reference:

$$\tan\frac{A}{2} = \frac{r}{s-a}, \qquad \tan\frac{B}{2} = \frac{r}{s-b}, \qquad \tan\frac{C}{2} = \frac{r}{s-c}$$

where

$$s = \frac{a+b+c}{2}$$

and

$$r = \sqrt{\frac{(s-a)(s-b)(s-c)}{s}} = \text{radius of inscribed circle.}$$

From these formulæ we have at once,

$$\text{Area} = rs = \sqrt{s(s-a)(s-b)(s-c)}.$$

29. The only case which is likely to give any difficulty, is the "ambiguous case" in which the given parts are two sides and the angle opposite one of them. Here we must remember, at a certain point in the work, that when the sine of an angle is given, there will be, in general, two angles corresponding to that sine, one the supplement of the other; so that from that point on, the problem breaks up into two separate problems. But if the sine of an angle is 1, then the only value for the angle is 90°; and if the sine is greater than 1, there is no corresponding angle, and the problem is impossible. It is advisable to construct a fairly accurate figure.

30. *Problems in oblique triangles, triangulation, etc.*

In every case at least a rough sketch should be drawn on which the known parts are clearly marked, and a "blank form" for the computation should be made out for the entire problem, before any of the quantities are looked up in the table.

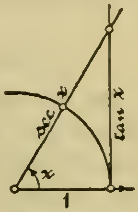
CHAPTER III.

GENERAL PROPERTIES OF THE TRIGONOMETRIC FUNCTIONS.

31. *Relations between the functions of a single angle.*—The student should convince himself that the following important relations will hold for any angle x:

$$\sin^2 x + \cos^2 x = 1, \quad \tan x = \frac{\sin x}{\cos x},$$

$$\sec^2 x = 1 + \tan^2 x.$$



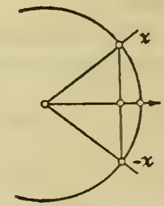
All these relations are easily recalled by the aid of the figures.

Somewhat less important is the following:

$$\csc^2 x = 1 + \cot^2 x.$$

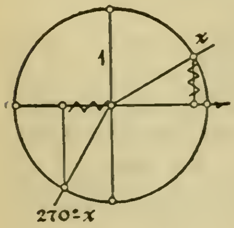
32. *Functions of* $(-x)$. From the figure,

$$\sin(-x) = -\sin x,$$
$$\cos(-x) = \cos x,$$
$$\tan(-x) = -\tan x.$$



33. *Functions of* $(90° + x)$, $(x + 180°)$, *etc.*—Any function of a combination like $(x \pm n90°)$ or $(n90° \pm x)$ can be expressed in terms of a function of x by the use of the figure.

For example, find $\sec(270° - x)$. Take as x any small angle in the first quadrant, and draw the angle $270° - x$.



Then, $\sec(270° - x)$ is 1 over the *cosine* of $(270° - x)$, which, pointing at the figure, is the radius over *this* line (〰), which is the same, in length, as the radius over *this* line (≷), which is 1 over the *sine* of x, or $\csc x$. But the signs are opposite; therefore,

$$\sec(270° - x) = -\csc x.$$

This method requires the memorizing of no rules or formulæ, besides the definitions of the functions; a very little practice will develop all the speed and accuracy that can be desired, and the method is one which is readily recalled to mind after long disuse. The special case of complementary angles, however, is worth remembering as a separate formula: Any function of $(90° - x) =$ the co-named function of x.

FORMULAS FOR THE SUM OF TWO ANGLES, ETC.

34. In simplifying trigonometric expressions which occur in calculus, mechanics, etc., the following formulæ are so frequently required that they should be thoroughly memorized. The ability to recognize those relations readily, regardless of the special lettering employed, is a necessary condition for rapid progress in almost any branch of analysis, but *it is highly undesirable to extend the list beyond the limits here given.*

The fundamental formulæ from which all others are derived are these two, the proof of which is obtained from a figure:

$$\sin (x + y) = \sin x \cos y + \cos x \sin y, \tag{1}$$

$$\cos (x + y) = \cos x \cos y - \sin x \sin y. \tag{2}$$

These and the following formulæ should be memorized in words, not in letters: thus, "the sine of the sum of two angles is the sine of the first times the cosine of the second, plus the cosine of the first times the sine of the second," etc.

Dividing (1) by (2) and then dividing numerator and denomerator by the product of the cosines, we have

$$\tan (x + y) = \frac{\tan x + \tan y}{1 - \tan x \tan y}. \tag{3}$$

Changing the sign of y in these three formulæ, and remembering the relations for negative angles, we have the corresponding formulæ for $\sin (x - y)$, $\cos (x - y)$, $\tan (x - y)$, which will be exactly the same as (1), (2), and (3) with all the connecting signs reversed:

(4) $$\sin(x-y)=\sin x\cos y-\cos x\sin y,$$

(5) $$\cos(x-y)=\cos x\cos y+\sin x\sin y,$$

(6) $$\tan(x-y)=\frac{\tan x-\tan y}{1+\tan x\ \tan y}.$$

Putting $x=y$ in (1), (2), and (3) we have at once

(7) $$\sin 2x=2\sin x\cos x,$$

(8) $$\cos 2x=\cos^2 x-\sin^2 x$$
$$=1-2\sin^2 x=2\cos^2 x-1,$$

(9) $$\tan 2x=\frac{2\tan x}{1-\tan^2 x}.$$

Solving (8) first for $\sin x$ and then for $\cos x$, and putting $2x=y$, or $x=y/2$, we find

(10) $$\sin\frac{y}{2}=\pm\sqrt{\frac{1-\cos y}{2}},$$*

(11) $$\cos\frac{y}{2}=\pm\sqrt{\frac{1+\cos y}{2}},$$

whence,

(12) $$\tan\frac{y}{2}=\pm\sqrt{\frac{1-\cos y}{1+\cos y}}.$$

This last formula may be transformed, by rationalizing numerator or denominator, into

$$\tan\frac{y}{2}=\frac{1-\cos y}{\sin y}=\frac{\sin y}{1+\cos y}.$$

Other formulas, useful for special purposes, should not be memorized, but should be derived as needed.

35. In proving the identity of two trigonometric expressions, it is best to reduce each expression separately to its simplest form.

---

* The *plus* sign is to be used when $\sin\frac{1}{2}y$ is positive, the *minus* sign when $\sin\frac{1}{2}y$ is negative. Similarly in the next two formulas.

The fallacy of supposing that because a true relation can be deduced from a given equation, the given equation is therefore necessarily true, should be carefully explained.

For example, from the false equation $3 = -3$ we can obtain the true equation $9 = 9$ by squaring both sides; or, from the false equation $30° = 150°$ we can obtain the true equation $\frac{1}{2} = \frac{1}{2}$ by taking the sine of both sides; but in each of these cases the step taken is not reversible.

36. The following device for transforming an expression of the form $a \cos x + b \sin x$ is often useful:

$$a \cos x + b \sin x = \sqrt{a^2 + b^2}\left[\frac{a}{\sqrt{(a^2+b^2)}} \cos x + \frac{b}{\sqrt{(a^2+b^2)}} \sin x\right]$$

$$= A \cos (x - B),$$

where $$A = \sqrt{(a^2 + b^2)} \text{ and } \tan B = \frac{b}{a}.$$

37. *The inverse functions.*

The angle between $-90°$ and $+90°$ whose sine is x is denoted by $\sin^{-1} x$.*

The angle between 0° and 180° whose cosine is x is denoted by $\cos^{-1} x$.

The angle between $-90°$ and $+90°$ whose tangent is x is denoted by $\tan^{-1} x$.

In simplifying expressions involving these "inverse functions," it is well to take a single letter to stand for each inverse function; as, $y = \sin^{-1} x$, whence, by definition, $\sin y = x$; etc.

38. *Solution of trigonometric equations.* Many trigonometric equations can be solved only by the "method of trial and error" (see chapter on numerical computation). In other cases, however, it is possible, by the use of the formulas given above, to transform the given equation into a form involving only a single function of a single angle; if this equation can be solved for the function in question, then the required value (or values) of the angle can be found from the tables or it can be shown that no solution exists.

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* The symbol $\sin^{-1} x$ (or arc sin x) is often defined as simply "the angle whose sine is x"; but since there are many such angles, it is necessary to specify which one is to be taken as "the" angle, if the symbol is to have any definite meaning.

A SYLLABUS OF ANALYTIC GEOMETRY.

This syllabus is intended to include those facts and methods of analytic geometry which a student who has completed an elementary course in that subject should have so firmly fixed in his memory that he will never think of looking them up in a book.

A course of study in analytic geometry should consist chiefly of *problems* solved by the students, each problem being solved on the basis of a small number of fundamental formulas such as are here mentioned.

This syllabus is confined mainly to the conic sections; but a satisfactory course in analytic geometry should include also the study of many other curves, both in rectangular and in polar coordinates. The syllabus takes up only those properties of curves which can be readily investigated without the aid of the calculus; but the present tendency to introduce the elements of the calculus *before* any elaborate study of geometry is attempted is to be much encouraged.

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Chapter VI. The Hyperbola: $b^2x^2 - a^2y^2 = a^2b^2$.
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CHAPTER I.

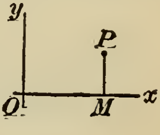
RECTANGULAR COORDINATES.

1. In many geometrical problems it is convenient to describe the position of a point in a plane by giving its distances from two fixed (perpendicular) lines in the plane.*

For example, on a map, the distance of a point to the east or west from a fixed meridian is called the longitude of the point, and its distance north or south from the equator is called its latitude.

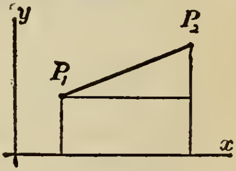
So in general, in any plane, the distance of a point to the right or left from a fixed vertical axis is called the *abscissa*, x, of the point, and its distance up or down from a fixed horizontal axis is called its *ordinate*, y. The x and y together are called the *coordinates* of the point.

The value of $x\,(=OM)$ will be positive to the right, negative to the left; the value of $y\,(=MP)$ will be positive upward, negative downward. The point for which $x = x_1$ and $y = y_1$ is denoted by P_1, or (x_1, y_1).



2. To express *the distance between two points* in terms of their coordinates:

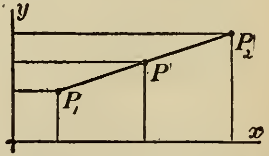
$$D = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}.$$



3. To find the coordinates of *the point half way between two given points:*

$$x = \tfrac{1}{2}(x_1 + x_2),$$

$$y = \tfrac{1}{2}(y_1 + y_2).$$



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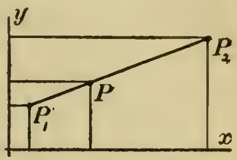
* We restrict ourselves here to *rectangular* axes; oblique axes are, however, occasionally useful.

4. *To find the coordinates of a point P on the line through two fixed points,* and such that its distance from the first point is n times the distance between the two points ($\overline{P_1P} = n\overline{P_1P_2}$):

$$x = x_1 + n(x_2 - x_1),$$

$$y = y_1 + n(y_2 - y_1).$$

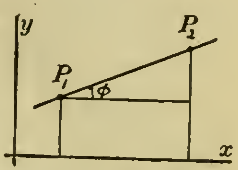


Here n may be any real number (positive, negative, or zero).

5. *To find the slope of a line through two given points:*

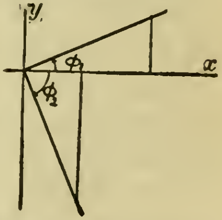
$$m = \tan\phi = \frac{y_2 - y_1}{x_2 - x_1}.$$

The angle ϕ is called the *inclination* of the line; $\tan\phi$ is the *slope.*



6. If two lines are *parallel,* their slopes are equal: $m_1 = m_2$.

If two lines are *perpendicular,* the product of their slopes is minus one: $m_1m_2 = -1$.



7. To express *the areas of triangles and polygons* in terms of the coordinates of the vertices, consider the trapezoids formed by the ordinates drawn to the vertices.

8. In any problem involving an unknown point, remember that *two conditions* are necessary to determine the coordinates of the point (simultaneous equations in two unknown quantities).

CHAPTER II.

THE STRAIGHT LINE: EQUATIONS OF THE FORM $Ax + By + C = 0$.

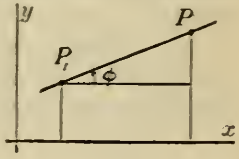
9. We have seen that if two conditions are imposed on x and y, the position of the point (x, y) is wholly determined. If only one condition is imposed, the position of the point is only partially restricted. (Examples: $x = 5$, $x^2 + y^2 = 25$, etc.)

The collection of all points which satisfy a given condition imposed on x and y is called the *locus* of that condition; and the condition itself, expressed in algebraic language, is called the *equation of the locus*. Thus, the *equation of a straight line* is the algebraic expression of the *condition* which x and y must satisfy in order that the point (x, y) shall lie on the line; in other words, *the equation of a line is an equation which is* TRUE *when the coordinates of any point on the line are substituted for x and y, and* FALSE *when the coordinates of any point off the line are substituted for x and y;* and so in general for the equation of any locus.

10. To find the coordinates of the points of intersection of two loci whose equations are given, we have simply to find the pairs of values of x and y (if any) which satisfy both the equations at once (simultaneous equations in x and y).

11. *To find the equation of a line* (not perpendicular to either axis), *when its slope, m, and the coordinates of one of its points (x_1, y_1), are given:*

$$y - y_1 = m(x - x_1).$$



The equation of a line perpendicular to the x-axis (or the y-axis) is, by inspection, $x = a$ (or $y = b$).

The equation of any straight line is of the form $Ax + By + C = 0$, and the locus of every equation of the form $Ax + By + C = 0$ is a straight line. Hence, to plot the locus of such an equation, it is sufficient to find any two of its points.

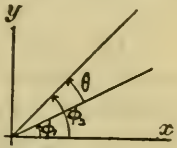
12. *To find the slope of a line whose equation is given* (the line being not perpendicular to an axis), write the equation in the form $y = (\ )\,x + (\ )$; then the coefficient of x will be the slope.

13. To find the equation of a line *parallel* or *perpendicular* to a given line and through a given point, remember that $m_1 = m_2$ for parallel lines, and $m_1 m_2 = -1$ for perpendicular lines (see § 6).

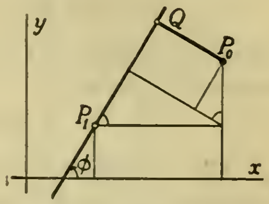
Special method: if the given line is $Ax + By + C = 0$, then the parallel is $Ax + By = k$ and the perpendicular is $Bx - Ay = K$, where k and K are to be determined.

14. *To find the angle θ between two lines whose slopes are given:*

$$\tan\theta = \frac{m_2 - m_1}{1 + m_2 m_1}.\text{*}$$



15. *To find the distance between a given point (x_0, y_0), and a given line:*



(*a*) When the inclination of the line, ϕ, and the coordinates of one of its points, (x_1, y_1), are given, we have from the figure:

$$\overline{QP_0} = (x_0 - x_1)\sin\phi - (y_0 - y_1)\cos\phi,$$

(*b*) When the equation of the line is given in the form $Ax + By + C = 0$, use the following formula:†

$$D = \left|\frac{Ax_0 + By_0 + C}{\sqrt{A^2 + B^2}}\right|.$$

Here the vertical bars mean "the absolute value of."

---

* Proof: By trigonometry, $\tan(\phi_2 - \phi_1) = \dfrac{\tan\phi_2 - \tan\phi_1}{1 + \tan\phi_2 \tan\phi_1}$.

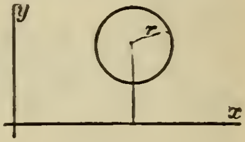
† Proof: Show that the foot of the perpendicular from P_0 to the line $Ax + By + C = 0$ has the coordinates $x_2 = x_0 - hA$, $y_2 = y_0 - hB$, where $h = (Ax_0 + By_0 + C) / (A^2 + B^2)$.

CHAPTER III.

THE CIRCLE: EQUATIONS OF THE FORM $x^2 + y^2 + Dx + Ey + F = 0$.

16. The *equation of a circle* is the algebraic expression of the *condition* which x and y must satisfy in order that the point (x,y) shall lie on the circle (see § 9 and § 10).

17. *To find the equation of a circle when its radius, r, and the coordinates* (α, β) *of its centre are given:*



$$(x - \alpha)^2 + (y - \beta)^2 = r^2.$$

When the centre is at the origin (0, 0), this equation becomes

$$x^2 + y^2 = r^2.$$

18. The equation of any circle is of the form $x^2 + y^2 + Dx + Ey + F = 0$. Conversely, every equation of the form $x^2 + y^2 + Dx + Ey + F = 0$ can be reduced to the form $(x + \frac{D}{2})^2 + (y + \frac{E}{2})^2 = \frac{1}{4}(D^2 + E^2 - 4F)$, and therefore represents a circle with centre at $(-D/2, -E/2)$, or a single point, or no locus, according as $D^2 + E^2 - 4F$ is positive, zero, or negative. When we say, in brief, that the locus of any equation of the form $x^2 + y^2 + Dx + Ey + F = 0$ is a "circle," we must understand that the "circle" may be "real," "null," or "imaginary."

19. *To find the centre and radius of a circle whose equation is given,* do not use a formula, but "complete the squares" of the terms in x and y in each case, and compare with the standard equation in the manner just indicated.

20. *In problems concerning tangents to a circle,* use the fact that the tangent is perpendicular to the radius drawn to the point of contact.

CHAPTER IV.

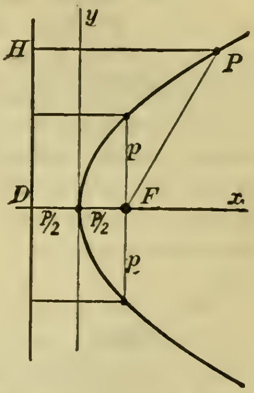
THE PARABOLA: $y^2 = 2px$.

21. Definition: The locus of a point which moves so that

$$\frac{\text{its distance from a fixed point}}{\text{its distance from a fixed line}} = 1$$

is called a *parabola*.

The fixed point is called the *focus* and the fixed line the *directrix.* The line perpendicular to the directrix through the focus is called the *principal axis*. There is evidently only one point of the principal axis which is also a point of the curve, namely the point half way between the focus and the directrix; this point is called the *vertex*.



22. If we take the vertex as the origin and the principal axis as the axis of x, the *equation of the parabola* is

$$y^2 = 2px,$$

where $p =$ the distance between focus and directrix.*

23. The form of the curve is therefore that shown in the figure.† By definition $PF = PH$ for every point P on the curve.

The breadth of the curve at the focus is called the *latus rectum*, and is equal to $2p$.

---

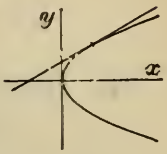
* Proof: If (x, y) is any point on the curve, then

$$\sqrt{(x - \tfrac{1}{2}p)^2 + (y - 0)^2} = x + \tfrac{1}{2}p.$$

Many British authors write the equation in the form $y^2 = 4ax$, to avoid fractions. Other writers use $y^2 = 4px$ for the same purpose; this latter form, however, is unfortunate, since $2p$ is a fairly well-established notation for the latus rectum in each of the conics.

† Thus when x is 0, y is 0. When x increases, y increases, plus and minus; the curve is symmetrical with respect to the x-axis. When x is negative, y is imaginary. When $x = p/2$, $y = \pm\ p$; when $x = 2p$, $y = \pm\ 2p$.

24. To find the *equation of a tangent* to the parabola $y^2 = 2px$, use one of the following formulas:



(*a*) When the point of contact, (x_1, y_1), is given:*

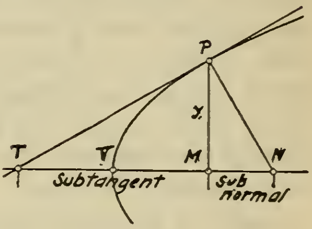
$$y_1 y = p(x + x_1);$$

(*b*) When the slope, m, is given:†

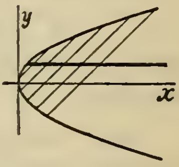
$$y = mx + \frac{p}{2m}.$$

A line perpendicular to a tangent at the point of contact is called a *normal.*

If the tangent and normal at any point P meet the principal axis at T and N, the projections of PT and PN on the principal axis are called the *subtangent* and *subnormal,* respectively. The subtangent is bisected by the vertex. The subnormal is constant, equal to the semi-latus rectum, p.



25. The locus of the middle points of a set of parallel chords in the parabola is a straight line parallel to the principal axis; such a line is called a *diameter.* In the parabola $y^2 = 2px$, if the slope of the parallel chords is m, then the equation of the diameter is $y = p/m$.‡



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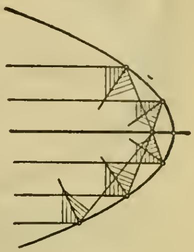
* Proof: Let $P_2 = (x_1 + h, y_1 + k)$ be a second point on the curve, near P_1; then the *slope of the tangent* at P_1 will be the limit of k/h as P_2 approaches P_1 along the curve, namely $m = p/y_1$. Then use § 11. The slope of the curve may also be found by the general method of the differential calculus.

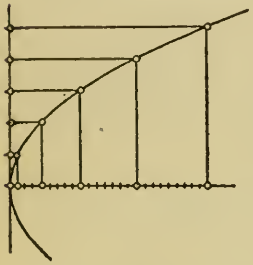
† Proof: Determine β so that the line $y = mx + \beta$ shall have only one point in common with the curve. [Remember that a quadratic equation $Ax^2 + Bx + C = 0$ will have equal roots if $B^2 - 4AC = 0$.]

‡ Proof: Let (x_0, y_0) be any point of the required locus; find the points of intersection of the curve and a line through (x_0, y_0) with slope m; then express the condition that (x_0, y_0) shall be the middle point between these two points. [Remember that the sum of the roots of a quadratic equation $Ax^2 + Bx + C = 0$ is $-B/A$.]

25a. Among the many properties of the parabola which should be worked out as problems, the following may be mentioned as especially important, and easy to remember:

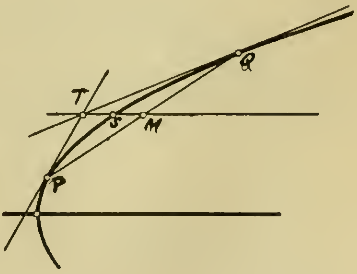
1. The normal at any point P bisects the angle formed by the line from P to the focus and the line through P parallel to the principal axis (parabolic mirror).

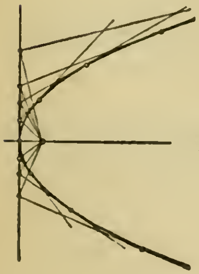




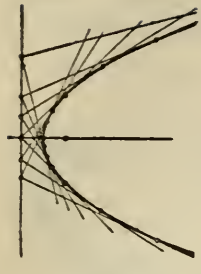
2. If P_1, P_2, ... are any points on a parabola, the distances of these points from the principal axis are proportional to the squares of their distances from the tangent at the vertex.

3. If the tangents at P and Q intersect at T, and if M is the middle point of the chord PQ, then the line through T and M is a diameter, and the segment TM is bisected by its point of intersection with the curve.





4. The locus of the foot of the perpendicular from the focus on a moving tangent is the tangent at the vertex.



5. The locus of the point of intersection of perpendicular tangents is the directrix.

Note. The usual methods for constructing a parabola should also be given.

CHAPTER V.

THE ELLIPSE: $b^2x^2 + a^2y^2 = a^2b^2$.

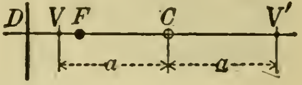
26. Definition: The locus of a point which moves so that

$$\frac{\text{its distance from a fixed point}}{\text{its distance from a fixed line}} = e < 1$$

(where e is a constant less than 1), is called an *ellipse.*

The fixed point is called the *focus,* the fixed line the *directrix,* and the constant, e, the *eccentricity.* The line perpendicular to the directrix through the focus is called the *principal axis.* There are evidently two points of the principal axis which are also points of the curve; these two points are called the *vertices,* and the point half way between them is called the *centre.*

27. If we let $2a =$ the distance between the vertices, then:*



the distance between the *centre* and either *vertex* is a;
the distance between the *centre* and the *focus* is ae;
the distance between the *centre* and the *directrix* is a/e.

28. If we take the centre as the origin and the principal axis as the axis of x, the *equation of the ellipse* is

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1,$$

where b is an abbreviation for $a\sqrt{1 - e^2}$.† Note that $b < a$.

---

[*] Proof: Since the vertices, V and V', are points of the curve, $VF/VD = e$ and $V'F/V'D = e$; that is,

$$\frac{a - CF}{CD - a} = e \quad \text{and} \quad \frac{a + CF}{a + CD} = e,$$

whence $CF = ae$ and $CD = a/e$.

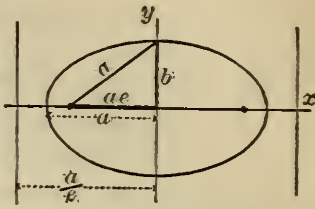
[†] Proof: If (x, y) is any point on the curve, then

$$\frac{\sqrt{(x + ae)^2 + (y - 0)^2}}{x + \frac{a}{e}} = e.$$

29. The form of the curve is therefore that shown in the figure.* The right triangle enables us to find any one of the three quantities a, b, and e, when the other two are given.

The symmetry of the equation shows that the curve might equally well have been obtained, with the same eccentricity, e, from a *second focus and directrix,* shown on the right.

The breadth of the curve at either focus is called the *latus rectum,* and is equal to $2a(1 - e^2)$, or $2b^2/a$.



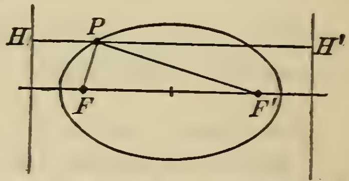
$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1.$$

30. Let P be any point of the ellipse, F and F' the foci, and PH and PH' the perpendiculars from P to the directrices; then

(*a*) $PF/PH = e$ and $PF'/PH' = e$,

by definition of the curve. Furthermore:†

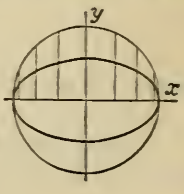
(*b*) $$PF + PF' = 2a.$$



In fact, the ellipse is often defined as *the locus of a point which moves so that the sum of its distances from two fixed points is constant.*

31. If a circle be described upon the major axis of an ellipse as diameter, each ordinate in the ellipse is to the corresponding ordinate in the circle as b is to a.‡ In fact, the ellipse is often defined as *the locus of points dividing the ordinates of a circle in a constant ratio.*

From this property it follows that the *area of an ellipse* is πab.



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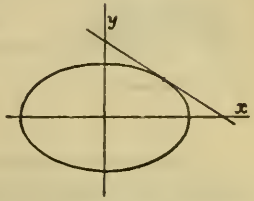
* Thus, when $y = 0$, $x = \pm a$; when $x = 0$, $y = \pm b$. The curve is symmetrical with respect to both axes. In first quadrant, as x increases, y decreases (slowly when x is small, and rapidly when x approaches a).

† Proof: $PF = e(PH)$ and $PF' = e(PH')$, so that $PF + PF' = e(HH') = e(2a/e) = 2a$.

‡ Proof: In the ellipse, $y = \frac{b}{a}\sqrt{a^2 - x^2}$; in the circle, $y = \sqrt{a^2 - x^2}$.

32. To find the *equation of a tangent* to the ellipse $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$, use one of the following formulas:*



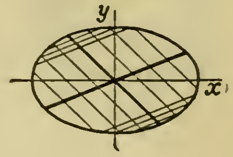
(*a*) When the point of contact, (x_1, y_1), is given:

$$\frac{x_1 x}{a^2} + \frac{y_1 y}{b^2} = 1;$$

(*b*) When the slope, m, is given:

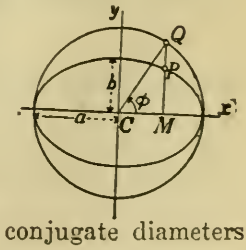
$$y = mx \pm \sqrt{a^2m^2 + b^2}.$$

33. The locus of the middle points of a set of parallel chords in the ellipse is a straight line through the centre; such a line is called a *diameter*. In the ellipse $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$, if the slope of the parallel chords is m, then the slope of the diameter is $-\frac{b^2}{a^2m}$.*



Any two lines through the centre, such that the product of their slopes is $-b^2/a^2$, are called a pair of *conjugate diameters*, because each bisects all chords parallel to the other.

34. The circle described in § 31 is called the *auxiliary circle.* If P is any point on the ellipse, and Q the corresponding point on the auxiliary circle (see figure), then the angle ϕ which CQ makes with the axis is called the *eccentric angle* of the point P. From the figure, and § 31,



$$x = a \cos\phi \quad \text{and} \quad y = b \sin\phi,$$

where x, y are the coordinates of P.

The eccentric angles of the ends of two conjugate diameters differ by 90°.

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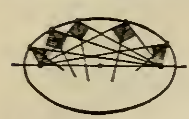
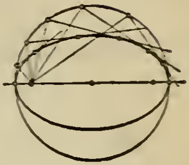
* Proof as in the case of the parabola.

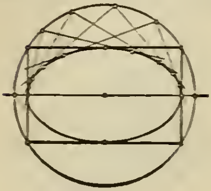
34a. Among the many properties of the ellipse that should be worked out as problems, the following are especially easy to remember:



1. The normal at any point P bisects the angle formed by the lines joining P with the foci.

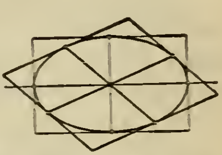
2. The locus of the foot of the perpendicular from the focus on a moving tangent is the circle on the major axis as diameter.





3. The locus of the point of intersection of perpendicular tangents is a circle with radius $\sqrt{a^2+b^2}$.

4. The area of a parallelogram bounded by tangents parallel to conjugate diameters is constant.



Note. The usual methods for constructing an ellipse should also be given.

CHAPTER VI.

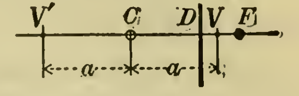
THE HYPERBOLA: $b^2x^2 - a^2y^2 = a^2b^2$.

35. Definition: The locus of a point which moves so that

$$\frac{\text{its distance from a fixed point}}{\text{its distance from a fixed line}} = e > 1$$

(where e is a constant greater than 1), is called a *hyperbola.*

The fixed point is called the *focus,* the fixed line the *directrix,* and the constant, e, the *eccentricity.* The line perpendicular to the directrix through the focus is called the *principal axis.* There are evidently two points of the principal axis which are also points of the curve; these two points are called the *vertices,* and the point half way between them is called the *centre.*



36. If we let $2a =$ the distance between the vertices, then:*

the distance between the *centre* and either *vertex* is a;
the distance between the *centre* and the *focus* is ae;
the distance between the *centre* and the *directrix* is a/e.

37. If we take the centre as the origin and the principal axis as the axis of x, the *equation of the hyperbola* is

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1,$$

where b is an abbreviation for $a\sqrt{e^2 - 1}$.† Note that b may be greater or less than a, or equal to a.

---

* Proof: Since the vertices, V and V', are points of the curve, $VF/VD = e$ and $V'F/V'D = e$; that is,

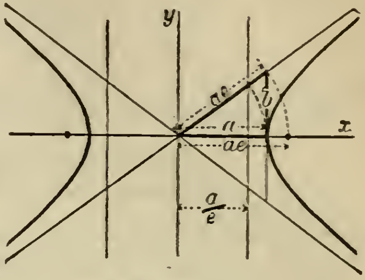
$$\frac{CF - a}{a - CD} = e \quad \text{and} \quad \frac{a + CF}{a + CD} = e,$$

whence $CF = ae$ and $CD = a/e$.

† Proof: If (x, y) is any point on the curve, then

$$\frac{\sqrt{(x - ae)^2 + (y - 0)^2}}{x - \frac{a}{e}} = e.$$

38. The form of the curve is therefore that shown in the figure.* The two lines through the centre with slopes $\pm b/a$ are called the *asymptotes* of the hyperbola; the two branches of the curve approach these lines more and more nearly as they recede from the centre.† The right triangle enables us to find any one of the three quantities, a, b, and e, when the other two are given.

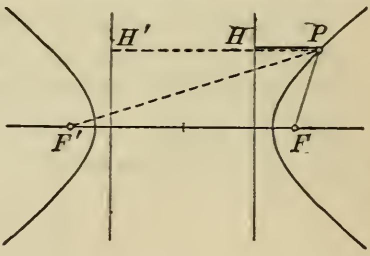


$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1.$$

The symmetry of the equation shows that the curve might equally well have been obtained, with the same eccentricity, e, from a *second focus and directrix*, shown on the left.

The breadth of the curve at either focus is called the *latus rectum*, and is equal to $2a(e^2 - 1)$, or $2b^2/a$.

39. Let P be any point of the hyperbola, F and F' the foci, and PH and PH' the perpendiculars from P to the directrices; then



(a) $PF/PH = e$ and $PF'/PH' = e$,

by the definition of the curve. Furthermore:‡

(b) $|PF - PF'| = 2a$.

In fact, the hyperbola is often defined as the *locus of a point which moves so that the difference of its distances from two fixed points is constant.*

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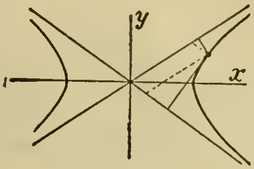
* Thus, when $y = 0, x = \pm a$; when $x = 0$, or $x < a$, y is imaginary; when x increases beyond a, y increases, plus and minus (most rapidly when x is little greater than a). The curve is symmetrical with respect to both axes.

† For, the slope $\frac{y}{x} = \frac{b}{a}\sqrt{1 - \frac{a^2}{x^2}}$ approaches $\frac{b}{a}$ as x increases; moreover, if y_1 is the ordinate of any point on the curve, and y_2 the ordinate of the corresponding point on the asymptote, then the difference $y_2 - y_1$ approaches zero; for $y_2^2 - y_1^2 = b^2$, and therefore $y_2 - y_1 = b^2/(y_2 + y_1)$.

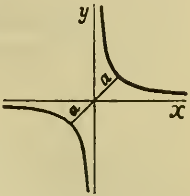
‡ Proof: $PF = e(PH)$ and $PF = e(PH')$, so that $|PF - PF'| = e(HH') = e(2a/e) = 2a$.

40. The product of the distances from any point of a hyperbola to the asymptotes is constant. Hence, the hyperbola is often defined as *the locus of a point which moves so that the product of its distances from two fixed lines is constant.* (The distances here may be the perpendicular distances; or, the distance to each line may be measured parallel to the other.)



41. An important special case is that of the "rectangular" hyperbola, whose asymptotes are perpendicular ($a = b$); the *equation of the rectangular hyperbola referred to its asymptotes as axes* is (by § 40)

$$xy = \frac{a^2}{2}.$$



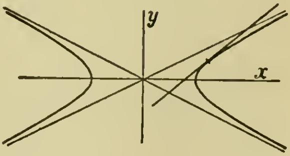
42. To find the *equation of a tangent* to the hyperbola $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$, use one of the following formulas:*

(a) When the point of contact, (x_1, y_1), is given:

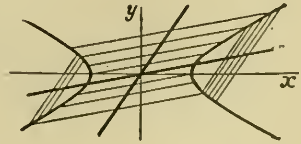
$$\frac{x_1 x}{a^2} - \frac{y_1 y}{b^2} = 1;$$

(b) When the slope, m, is given:

$$y = mx \pm \sqrt{a^2 m^2 - b^2}.$$



43. The locus of the middle points of a set of parallel chords in the hyperbola is a straight line through the centre; such a line is called a *diameter*. In the hyperbola $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$, if the slope of the parallel chords is m, the slope of the diameter will be $\frac{b^2}{a^2 m}$.*



Any two lines through the centre, such that the product of their slopes is b^2/a^2, are called a pair of *conjugate diameters*, because each bisects all chords parallel to the other.

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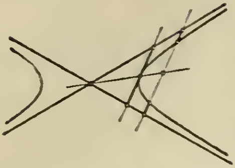
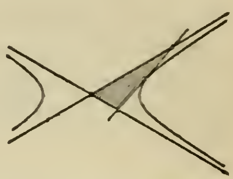
* Proof as in the case of the parabola.

43a. Among the properties of the hyperbola, the following are easy to remember:



1. If a line cuts the hyperbola and its asymptotes, the parts of the line intercepted between the curve and the asymptotes are equal. In particular, the portion of any tangent intercepted between the asymptotes is bisected by the point of tangency.

2. The area of the triangle bounded by any tangent and the asymptotes is constant.



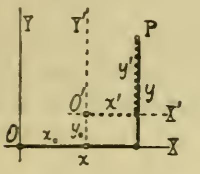
Note. The usual methods of constructing a hyperbola—especially the rectangular hyperbola—should be given.

CHAPTER VII.

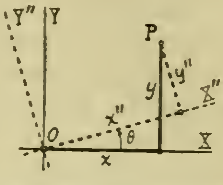
TRANSFORMATION OF COORDINATES.*

44. The equation of a curve can often be simplified by a "change of axes," either changing to a new origin (x_0, y_0), or turning the axes through an angle θ, or both.

If (x, y), (x', y'), (x'', y''), are the coordinates of the same point P, referred to three different sets of axes, as in the figures, then



$$x = x_0 + x'$$
$$y = y_0 + y'$$



$$x = x'' \cos\theta - y'' \sin\theta \dagger$$
$$y = x'' \sin\theta + y'' \cos\theta$$

Suppose now that the point P is allowed to move under certain conditions given by an equation in x and y. The same condition can be expressed in terms of x' and y' or in terms of x'' and y'' by substituting in the given equation the values of x and y just found. This process is called a transformation of coordinates, from the axes x, y to the axes x', y', or to the axes x'', y''; and the new equation can often be made simpler than the given equation by a suitable choice of x_0 and y_0, or θ.

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[*] See also the chapter on polar co-ordinates.

[†] These last formulas are most easily remembered as follows:

$x =$ easterly displacement of P,
$=$ (easterly component of x'') $+$ (easterly component of y'')
$= x'' \cos\theta - y'' \sin\theta'$,
$y =$ northerly displacement of P
$=$ (northerly component of x'') $+$ (northerly component of y'')
$= x'' \sin\theta + y'' \cos\theta$.

CHAPTER VIII.

GENERAL EQUATION OF THE SECOND DEGREE IN x AND y.

45. The general equation of the second degree in x and y is of the form

$$Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0.$$

By a suitable transformation of coördinates this equation can always be brought into one or other of the following forms:

$$A'x^2 + C'y^2 + F' = 0, \quad C''y^2 + D''x = 0, \quad C''y^2 + F'' = 0,$$

and hence can be shown to represent a conic section, using this term in a general sense to include (1) an ellipse, which may be real, null, or imaginary; (2) a hyperbola, or a pair of intersecting lines; (3) a parabola, or a pair of parallel lines (distinct, coincident, or imaginary).*

The student should be able to plot readily the locus of an equation of the second degree in any of the simple cases mentioned below—these being the cases which occur most often in practice.

46. To plot $Ax^2 + Cy^2 + F = 0$, where A and C have the same sign. Find the intercepts on the axes (by putting $x = 0$ and $y = 0$); if both are real, we have an ellipse in which $a =$ the larger of the two intercepts, and $b =$ the smaller; or if $A = C$, the ellipse becomes a circle. If both intercepts are zero, or imaginary, the locus is a single point, or imaginary.

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* Proof: If $B^2 - 4AC$ is not zero, transform to parallel axes with origin at (x_0, y_0), and choose x_0 and y_0 so that the terms of the first degree in the new equation shall vanish; then turn the axes through an angle θ, and choose θ so that the term in xy shall vanish. If $B^2 - 4AC = 0$, turn the axes through an angle θ, and choose θ so that the term in xy shall vanish; then transform to a new origin (x_0, y_0), and choose x_0 and y_0 so that the constant term and one of the terms of the first degree, or so that both the terms of the first degree shall vanish. For special methods of abbreviating the computation in numerical cases see § 55, note.

47. To plot $Ax^2 + Cy^2 + F = 0$, where A and C have opposite signs. Unless $F = 0$, one of the intercepts will be real and the other imaginary, and the curve will be a hyperbola whose principal axis is the axis on which the intercepts are real. To find the slopes of the asymptotes, divide by x^2 and find the limit of y/x as x increases indefinitely. If $F = 0$, the locus is a pair of intersecting lines.

48. To plot $Cy^2 + Dx + F = 0$. Write this as

$$y^2 = -\frac{D}{C}\left(x + \frac{F}{D}\right), \quad \text{or} \quad y^2 = -\frac{D}{C}x'.$$

This is a parabola with vertex at $x_0 = -F/D$, and running out along the positive or negative axis of x. Plotting one or two points will fix the direction, and comparison with the equation $y^2 = 2px$ will give the semi-latus rectum, p.

49. To plot $Ax^2 + Cy^2 + Dx + Ey + F = 0$. Write this in the form

$$A\left(x^2 + \frac{D}{A}x + \quad\right) + C\left(y^2 + \frac{E}{C}y + \quad\right) = -F,$$

and "complete the squares"; then reduce to the form $Ax'^2 + Cy'^2 + F = 0$ by an obvious change of origin.

50. To plot $Cy^2 + Dx + Ey + F = 0$. Complete the square of the terms in y and reduce to the form $Cy^2 + Dx + F = 0$ by an obvious change of origin.

51. To plot $Bxy + F = 0$. This is a rectangular hyberbola referred to its asymptotes (see § 41). The equation $Bxy + Dx + Ey + F = 0$ can be reduced to this form by moving the origin to $x_0 = -E/B$, $y_0 = -D/B$.

52. If the equation to be plotted does not come under any of the forms just considered, a fair idea of the position of the curve may be found by the following very elementary method. Solving the equation for y in terms of x, we have, if C is not zero,

$$y = -\frac{Bx + E}{2C} \pm \frac{1}{2C}\sqrt{X},$$

where X is an expression involving x alone. Finding the values of $-(Bx+E)/2C$, and adding and subtracting the values of $\sqrt{X}/2C$, for various values of x, we can find as many points (x, y) on the curve as we please. Or, again, solving for x in terms of y, we have, if A is not zero,

$$x = -\frac{By+D}{2A} \pm \frac{1}{2A}\sqrt{Y}.$$

where Y is an expression involving y alone. From this equation we can find values of x corresponding to as many values of y as we please.

This method is very easy to remember, but does not give readily the exact dimensions of the curve.

53. The center of the curve will be the point of intersection of the two lines

$$2Ax + By + D = 0, \text{*}$$
$$Bx + 2Cy + E = 0,$$

except when $B^2 - 4AC = 0$, in which case these lines will be parallel, and the curve has no center.

54. The slopes of the lines joining the origin with the infinitely distant points of the curve (if any) are given by writing the terms of the second degree equal to zero:

$$Ax^2 + Bxy + Cy^2 = 0,$$

dividing through by x^2 (or y^2), and solving for y/x (or x/y).

55. If a more detailed discussion of the curve is required, it is best to follow the special methods of reduction given in the text-books (compare foot-note in § 45).†

56. The student should be familiar with the geometric proof that all the "conic sections" can be obtained as plane

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[*] The student of the calculus will recognize these equations as

$$\partial F/\partial x = 0 \quad \text{and} \quad \partial F/\partial y = 0,$$

where

$$F(x, y) \equiv Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0$$

is the equation of the curve.

[†] The resulting formulæ are given here for reference, although the problem is not one of common occurrence.

Required, to plot the equation $Ax^2 + Bxy + Cy^2 + Dx + Ey + F = 0$.

sections of a right circular cone. It is a profitable exercise to construct a cone, given the vertex and a hyperbolic section. It should also be made thoroughly clear why an elliptic section is a symmetrical figure instead of egg-shaped.

Case I. *Central conic.* If B^2-4AC is not zero, transform to the center as a new origin:

$$x_0=(2CD-BE)/(B^2-4AC),\ y_0=(2AE-BD)/(B^2-4AC);$$

then turn the axes through a positive acute angle θ given by

$$\tan 2\theta=B/(A-C).$$

The transformed equation will be

$$A'x^2+C'y^2+F'=0,$$

where $F'=Dx_0/2+Ey_0/2+F$, while A' and C' are found by solving the equations $A'+C'=A+C$, $A'-C'=\pm\sqrt{(A-C)^2+B^2}$, where the sign before the radical is to be + or — acording as B is positive or negative. The reduced equation can be plotted as in §§ 46, 47.

Case II. *Parabolic type.* If $B^2-4AC=0$, the equation may be written in the form $(ax+cy)^2+Dx+Ey+F=0$, where $a=\sqrt{A}$ while $c=\sqrt{C}$ or $c=-\sqrt{C}$ according as B is positive or negative. The locus will be of the parabolic type. Take as a new axis of x' the line

$$ax+cy+m=0,$$

where $m=(aD+cE)/2(A+C)$, and choose the positive direction along this line so that it shall make a (positive or negative) acute angle with the axis of x. This line will be the principal axis of the curve.

Two subcases may now occur.

(*a*) If a/c is not equal to D/E, take as axis of y' the line

$$cx-ay+n=0,$$

where $n=(A+C)\ (m^2-F)/(aE-cD)$. This line will be the tangent at the vertex, and the transformed equation will be

$$y'^2=2px',$$

where $2p=(cD-aE)/\sqrt{(A+C)^3}$. The locus is a true parabola.

(*b*) If $a/c=D/E$, the equation referred to the axis of x' will be

$$y'^2=m^2-F,$$

which represents a pair of distinct, coincident, or imaginary parallel lines.

CHAPTER IX.

SYSTEMS OF CONICS.

57. If U and V are expressions of the second degree in x and y, the equations $U=0$ and $V=0$ will represent conics; then (a) the equation $U+kV=0$, where k is any constant, will represent another conic passing through all the points of intersection of the first two, and having no other points in common with either of them; and (b) the equation $UV=0$ will represent a curve made up of the two conics $U=0$ and $V=0$ taken together. Corresponding theorems hold good if U and V are any expressions in x and y (not necessarily of the second degree).

58. To find the equation of a conic through five points, let $u=0$ and $v=0$ be the equations of the lines P_1P_2 and P_3P_4, and let $u'=0$ and $v'=0$ be the equations of the lines P_1P_3 and P_2P_4. Then $uv+ku'v'=0$, where k is any constant, will be the equation of a conic through these four points. It remains to determine k so that this conic shall pass through P_5.

59. The equation

$$\frac{x^2}{a^2+k}+\frac{y^2}{b^2+k}=1,$$

where k is an arbitrary constant, represents a family of confocal ellipses and hyperbolas, which intersect at right angles.

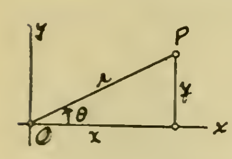
CHAPTER X.

POLAR COORDINATES.

This chapter, placed here for convenience of reference, may well be introduced, in teaching, much earlier in the course.

60. It is often convenient to represent the position of a point P by giving the angle, ϕ, which the line through O and P makes with the x-axis, and the distance, r, from O to P along this line. The angle ϕ is called the *vectorial angle,* or simply the *angle,* of the point P, and is measured from the positive direction of the axis of x to the positive direction of the line through O and P. The distance $r = OP$ is called the *radius vector* of the point P, and is positive or negative according as it runs forward or backward along the line through O and P.

It is customary to take r positive, and let ϕ range from 0° to 360°.



61. From the figure,

$$x = r\cos\phi, \quad y = r\sin\phi,$$

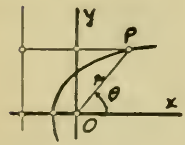
$$x^2 + y^2 = r^2, \quad y/x = \tan\phi.$$

By the aid of these relations, we can transform any equation from rectangular to polar coordinates, and vice versa.

62. The polar equation of a conic, referred to the focus as origin, and the principal axis as axis of x (see figure) is

$$r = \frac{p}{1 - e\cos\theta},$$

where p is the semi-latus rectum, and e the eccentricity.



63. Plotting curves in polar coordinates is an excellent exercise in reviewing the trigonometric functions. The work should be so arranged that no critical value of the function occurs between two successive assigned values of θ.

CHAPTER XI.

COORDINATES IN SPACE.

64. Four methods are in use for representing numerically the position of a point in space. If Ox, Oy, Oz are three mutually perpendicular axes, the position of any point P may be determined by:

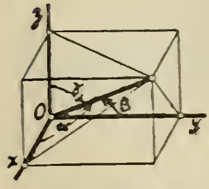
(1) Rectangular coordinates, x, y, z;

(2) Polar coordinates in space, r, α, β, γ, where the angles α, β, γ are subject to the restriction $\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$;

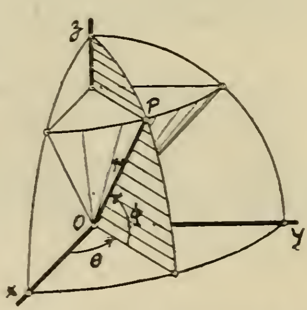
(3) Spherical coordinates, r, ϕ, θ, where $\phi =$ the latitude of P, and θ its longitude:

(4) Cylindrical coordinates ρ, θ, z.

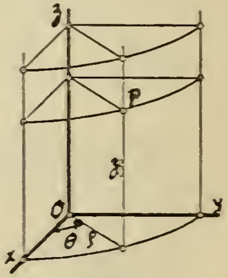
The relations between the various sets of coordinates are as follows:



$$x = r\cos\alpha,$$
$$y = r\cos\beta,$$
$$z = r\cos\gamma.$$



$$x = r\cos\phi\cos\theta$$
$$y = r\cos\phi\sin\theta$$
$$z = r\sin\phi$$

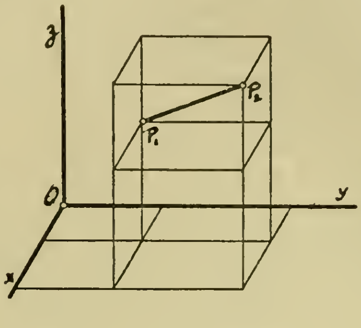


$$\rho = r\cos\phi,$$
$$\rho^2 = x^2 + y^2,$$
$$x^2 + y^2 + z^2 = r^2.$$

As there is no well-established uniformity in the use of the letters in spherical coordinates, or in the choice of the positive directions along the axes, it is important, in reading any author, to note, on a figure, the exact meanings of the letters he employs.

65. Distance between two points, in terms of their coordinates:

$$P_1P_2 = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2}.$$

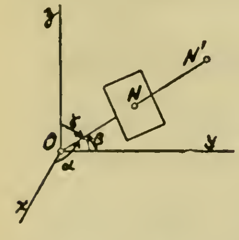


66. Angle ψ between two lines whose direction cosines are given:

$$\cos\psi = l_1l_2 + m_1m_2 + n_1n_2,$$

where $l_1 = \cos\alpha_1$, $m_1 = \cos\beta_1$, $n_1 = \cos\gamma_1$, etc.*

67. Equation of a plane:



$$lx + my + nz = p,$$

where p = perpendicular distance from the origin, and l, m, n = the direction cosines of the normal to the plane.†

Every equation of the form $Ax + By + Cz + D = 0$ represents a plane; for, it can be thrown into the form $lx + my + nz = p$ by dividing through by $\sqrt{A^2 + B^2 + C^2}$.

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* Proof: let (1) and (2) be lines through the origin, parallel to the given lines; on these lines take points P_1, P_2 at a distance r from the origin; then

$P_1P_2^2 = r^2 + r^2 - 2rr\cos\psi = (rl_1 - rl_2)^2 + (rm_1 - rm_2)^2 + (rn_1 - rn_2)^2$.

† Proof: The foot of the perpendicular is $N = (pl, pm, pn)$; take $N' = (2pl, 2pm, 2pn)$ and express the condition that the point (x, y, z) shall be equidistant from O and N'.

68. Equation of sphere with center at the origin:

$$x^2 + y^2 + z^2 = r^2.$$

69. Equation of ellipsoid, with center at the origin:

$$x^2/a^2 + y^2/b^2 + z^2/c^2 = 1.$$

70. Any equation in x, y, z will represent a surface (real or imaginary), the form of which can be investigated by the *method of plane sections.* Thus, putting $x = x_1$, the equation becomes an equation in y and z, which represents a curve in the plane $x = x_1$; similarly for $y = y_1$ and $z = z_1$.

71. Any equation of the second degree in x, y, z represents a (real or imaginary) surface of the second degree, or *conicoid.* The types of real conicoids are as follows:

(1) *Ellipsoid,* with semi-axes a, b, c. Special case: ellipsoid of revolution, generated by rotating an ellipse about its major axis (prolate spheroid) or about its minor axis (oblate spheroid).

(2) *Hyperboloid of two sheets.* Special case: generated by rotating a hyperbola about its principal axis.

(3) *Hyperboloid of one sheet,* or *ruled hyperboloid.* Special case: generated by rotating a hyperbola about its conjugate axis. Two sets of straight lines can be drawn on this surface.

(4) *Elliptic paraboloid.* Special case: generated by rotating a parabola about its principal axis.

(5) *Hyperbolic paraboloid,* or *ruled paraboloid.* A saddle-shaped figure, on which two sets of straight lines can be drawn.

(6) *Cone,* generated by a straight line always passing through a fixed point called the vertex, and always touching a fixed conic, called the directrix. If the directrix is a circle, the cone is a circular cone (right or oblique). If the vertex recedes to infinity, the cone becomes a cylinder. On any cone a single set of straight lines can be drawn.

The student should become familiar with at least the shapes of these surfaces, through diagrams or models.

Any plane section of any surface of the second degree is a conic.

A SYLLABUS OF DIFFERENTIAL AND INTEGRAL CALCULUS.

This syllabus is intended to include those facts and methods of the calculus which every student who has completed an elementary course in the subject should have so firmly fixed in his memory that he will never think of looking them up in a book. The topics here mentioned are therefore not by any means the only topics that should be included in a course of study, nor does the arrangement of these topics, as classified in the following table of contents, necessarily indicate the order in which they should be presented to a beginner.

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* In preparation.

CHAPTER I.

FUNCTIONS AND THEIR GRAPHICAL REPRESENTATION.

1. **Function and argument.**—In many problems in practical life we have to deal with the relation between two variable quantities, one of which depends on the other for its value.

For example, the temperature of a fever patient depends on the time; the velocity acquired by a falling body depends on the distance fallen; the weight of an iron ball depends on its diameter, etc.

In general, if any quantity y depends on another quantity x, then y is called a *function* of x, written, for brevity, $y = f(x)$, and the independent variable x is called the *argument* of the function. More precisely stated, the notation $y = f(x)$ means that to every value of the argument x (within the range considered), there corresponds some definite value of the function, y; the value of y, or $f(x)$, corresponding to any particular value $x = a$ is denoted by $f(a)$.

If several values of y correspond to each value of x, we have what is called a "multiple valued function of x," which is really a collection of several distinct functions. For example, if $y^2 = x$, then $y = \pm\sqrt{x}$, which is a double valued function of x.

Any mathematical expression involving a variable x is a function of x; but there are many important functional relations which cannot be expressed in any simple mathematical form.

2. A function is said to be *tabulated* when values of the argument (as many as we please, preferably at regular intervals) are set down in one column, and the corresponding values of the function are set down in another column, opposite the first. For example, in a table of sines, the angle is the argument, and the sine of the angle is the function.

3. A function may also be exhibited *graphically,* as follows: Lay off the values of the argument as abscissas along a (horizontal) axis, Ox, and at each point of the axis erect an ordi-

nate, y, whose length shall indicate the value of the function at that point; a curve drawn through the tops of these ordinates is called the *curve*, or the *graph*, of the function. It should be clearly understood, however, that it is the height of the ordinate up to the curve, rather than the curve itself, that represents the function.

In plotting the curve for any function, it is important to indicate on each axis the scale which is used on that axis, and the name of the unit. For example, if we plot distance as a function of the time, the units on the y-axis may represent feet, and those on the x-axis, seconds.*

The obvious method of obtaining the graph of the sum or difference of two functions directly from the graphs of those functions should be noted.

4. The elementary mathematical functions.—In many important cases, the relation between the function and the argument can be expressed by a simple mathematical formula. For example, if $s =$ the distance fallen from rest in the time t, then $s = \frac{1}{2}gt^2$. In such cases, the value of the function for any given value of the argument can be found by simple substitution in the formula.

The most important elementary mathematical functions are the following:

Algebraic functions: cx, c/x; x^2, x^3; $\sqrt{x}$ (x positive).

Here $\sqrt{x} =$ the positive value of y for which $y^2 = x$.

Trigonometric functions: $\sin x$, $\cos x$, $\tan x$ (x in radians).

Exponential function: e^x ($e = 2.718\ldots$).

Logarithmic function: $\log_e x$ (x positive).

The student should be thoroughly familiar with the curves of each of these functions, so as to be able to sketch them, or visualize them, at any moment; many of the essential properties of the functions can be obtained by inspection of the curve.

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* It is not necessary that the lengths representing the units of x and y shall be equal; scales should be so chosen that the completed graph is of convenient size to fit the paper. In applications to geometry, however (see Chapter VI), the scales must be equal.

He should also be familiar with the formulas necessary for handling expressions involving these functions. The better drilled the student is in this formal algebraic work, the more rapid progress can he make in the really vital parts of the subject. (See chapters of this report on algebra and trigonometry.)

5. Next in importance are the following: the *hyperbolic functions,* which are coming more and more into use:

$$\sinh x = (e^x - e^{-x})/2, \quad \cosh x = (e^x + e^{-x})/2,$$
$$\tanh x = (e^x - e^{-x})/(e^x + e^{-x});$$

the *inverse trigonometric functions:*

$\sin^{-1} x =$ the angle between $-\pi/2$ and $+\pi/2$ radians (inclusive) whose sine is x;*
$\cos^{-1} x =$ the angle between 0 and π (inclusive) whose cosine is x;
$\tan^{-1} x =$ the angle between $-\pi/2$ and $+\pi/2$ (inclusive) whose tangent is x;

and the *inverse hyperbolic functions:*

$\sinh^{-1} x =$ the value of y for which $\sinh y = x$;
$\cosh^{-1} x =$ the positive value of y for which $\cosh y = x$;
$\tanh^{-1} x =$ the value of y for which $\tanh y = x$.

It should be noticed that the curves for the inverse functions can be obtained from the curves for the direct functions by rotating the plane through 180° about the line bisecting the first quadrant.

Formulas for the hyperbolic functions resemble those for the trigonometric functions, but the differences are so confusing that it is better not to try to memorize any formulas for the hyperbolic functions, but to look them up whenever they are needed. (The list in B. O. Peirce's Table of Integrals, for example, is entirely adequate.)

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* The symbol $\sin^{-1} x$ is often defined as simply "the angle whose sine is x"; but since there are many such angles, it is necessary to specify which one is to be taken as "the" angle, if the symbol is to have any definite meaning. Thus, if $\sin x = \frac{1}{2}$, x may equal $\pi/6$, or $5\pi/6$, etc.; but only one of these values, namely $\pi/6$, is properly denoted by the symbol $\sin^{-1} \frac{1}{2}$. Similarly for $\cos^{-1} x$ and $\tan^{-1} x$; and also for $\cosh^{-1} x$, which is like $\sqrt{x}$ in this respect. The conventions adopted to avoid ambiguity may be readily recalled from the figure, if we note that in each case the complete curve consists of two or more "branches," and that that one is taken as the "principal branch" which passes through the origin, or which lies nearest the origin on the positive side of the x-axis.

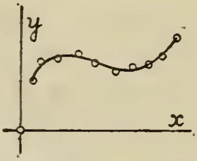
6. Continuity. A function $y = f(x)$ is said to be *continuous* at a given point $x = a$, if a small change in x produces only a small change in y; or more precisely, if $f(x)$ always approaches $f(a)$ as a limit when x approaches a in any manner.

A function may be *dis*continuous at a given point in three ways: (1) it may become infinite at that point, as $y = 1/x$ at $x = 0$; or (2) it may make a finite jump, as $y = \tan^{-1}(1/x)$ at $x = 0$;* or (3) the limit $\underset{x=a}{\mathrm{L}} f(x)$ may fail to exist because of the oscillation of the function in the neighborhood of $x = a$, as $y = \sin 1/x$ at $x = 0$. In each of these cases, the function is, properly speaking, not defined at the point in question.

A good example of a discontinuous function is the velocity of a shadow cast by a moving object on a zig-zag fence.

In what follows, we shall confine our attention to functions that are continuous, or that have only isolated points of discontinuity.

7. To find a mathematical function to represent an empirically given curve.—In many cases the form of the function is given only empirically; that is, the values of the function for certain special values of the argument are given by experiment, and the intermediate values are not accurately known (for example, the temperature of a fever patient, taken every hour). In such cases, the methods of the calculus are not of much assistance, unless some simple mathematical law can be found which represents the function sufficiently accu-



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* This function approaches $\pi/2$ when x approaches 0 from above, and $-\pi/2$ when x approaches 0 from below.

rately.* *This problem of finding a mathematical function whose graph shall pass through a series of empirically given points* is a very important one, which is much neglected in the current text-books. The complete discussion of the problem involves, it is true, the theory of least squares, which would undoubtedly be out of place in a first course in the calculus; but an elementary treatment of the problem in simple cases would be very desirable.†

The curves which are most likely to be worth trying, in any given case, are these:

$$y = a + bx \text{ (straight line)};$$

$$y = a + bx + cx^2 \text{ (parabola)};$$

$$y = a + c/(x + b) \text{ (hyperbola)};$$

$$y = a \sin (bx + c) \text{ (sine curve); and}$$

$$y = ax^m.$$

In testing this last curve, put $y' = \log y$, $x' = \log x$, and $a' = \log a$, and see whether y' and x' satisfy the straight line relation $y' = a' + mx'$; the use of "logarithmic squared paper" greatly facilitates the process.

The student should be familiar with all the possible forms of these curves, for various values of the constants a, b, c, and m.

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* If no simple law can be found to represent the entire curve, it is sometimes possible to break up the curve into parts, and find a separate law for each part.

† Numerous examples may be found in John Perry's "Practical Mathematics," and in F. M. Saxelby's "Practical Mathematics" (Longmans, 1905).

CHAPTER II.

DIFFERENTIATION. RATE OF CHANGE OF A FUNCTION.

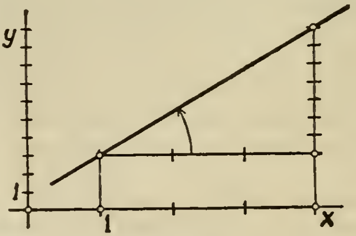
For the sake of clearness, this chapter is divided into four parts, A, B, C, D.

A. DEFINITIONS AND NOTATION.

8. Rate of change of function; slope of curve.—Given a function, $y=f(x)$, one of the most important questions we can ask about it is, what is the *rate of change* of the function at a given instant?

For example, the distance of a railroad train from the starting point is a function of the time elapsed, and we may ask, what is the rate of change of this distance? The answer is, so-and-so many *miles per hour.* Again, the volume of a metal sphere is a function of the temperature, and we may ask, what is the rate of change of this volume? The answer is, so-and-so many *cubic inches per degree.*

If the graph of the function is a straight line, then clearly the rate of change of the function will be constant; for, at any instant, (change in y)/(change in x) = the slope of the line.



If the scales along x and y are the same, the *slope of the line* = tan ϕ, where ϕ is the angle which the line makes with the x axis. If the scales are not the same, the slope of the line may still be interpreted as the ratio of the "side opposite" to the "side adjacent" in the triangle of reference for ϕ, provided each side is measured in the proper units. For example, in the figure, slope = 7/3.

If the graph is not a straight line, the meaning of "rate of change" at a given instant must be made more precise, as follows: Consider a particular value, $x = x_0$; give x an arbitrary change, Δx, and compute the corresponding change in y, namely, $\Delta y = f(x_0 + \Delta x) - f(x_0)$. Then the ratio $\Delta y/\Delta x$ may be called the AVERAGE *rate of change of the function during the interval from* $x = x_0$ *to* $x = x_0 + \Delta x$. (Geometrically, $\Delta y/\Delta x$ is the slope of the secant PQ in the figure.) Now let Δx approach zero, so that the interval in question closes down about the point $x = x_0$. Then *the ratio* $\Delta y/\Delta x$ *will in general approach a definite limit, and this limit is called the* ACTUAL *rate of change at the point* $x = x_0$. (Geometrically, the limit of $\Delta y/\Delta x$ is the slope of the tangent at P.*)

9. Derivatives. The *rate of change* of a function $y = f(x)$ at any point, or the *slope of the curve* at that point, is called the **derivative** of the function at that point, and is denoted by $f'(x)$, or $D_x y$, or y'.

The notation y is also used, but only when the independent variable is the time.

This definition of the derivative of a function as the limit of $\Delta y/\Delta x$ is the fundamental concept of the differential calculus. It is desirable that the meaning of the definition be made perfectly clear, by numerous and varied illustrations, before any formal work in differentiation is taken up.

10. Increments and Differentials.—The value Δx is called the *increment* given to x, and Δy the corresponding *increment* produced in y. The value that Δy *would have* if the curve coincided with its tangent (see figure) is called the **differential** *of y* and is denoted by dy.

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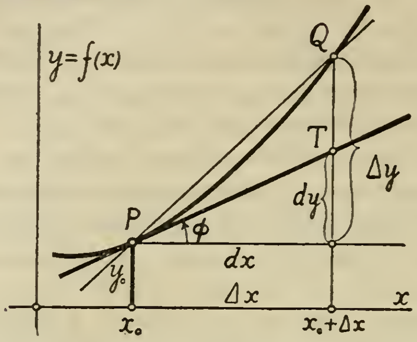
* The sense in which the tangent line is the "limit" of the secant lines should be made thoroughly clear. First, the tangent is a *fixed* line; secondly, the secant is a *variable* line, depending on the value given to Δx (that is, for every value of Δx, except the value 0, there is a corresponding position of the secant); thirdly, the angle between the tangent and the secant can be made to become *and remain* as small as we please by taking Δx sufficiently small. The tangent line itself does not in general belong to the series of secant lines; it is not in any sense the "last one" of the secants; it is a separate line, which bears a special relation to the series of secant lines, as described. The student may readily convince himself that the tangent is the *only* line through P that has the property just stated.



In case of the independent variable x, the differential of x is, by definition, the same as the increment: $dx = \Delta x$.

The use of differentials gives us a *new notation for the derivative,*

$$f'(x) = \frac{dy}{dx}.$$

Both these notations are in common use.

Notice that Δy and dy are both variables which approach zero when we make Δx approach zero; dy/dx is a constant, equal to $\tan\phi$; $\Delta y/\Delta x$ is a variable, approaching $\tan\phi$ as a limit. Hence we may write:

$$\lim_{\Delta x \doteq 0} \frac{\Delta y}{\Delta x} = f'(x) = D_x y = \frac{dy}{dx} = \tan\phi,$$

and

$$dy = f'(x)dx.$$

These relations between increments, differentials, and derivatives should be thoroughly mastered; they are readily recalled by the figure. Note especially that Δx and dx are quantities measured in the same unit as x; and Δy and dy in the same unit as y; while the derivative, dy/dx, that is, the slope, is (in general) measured in a compound unit (like miles per hour).

If the lengths representing the units of x and y are not equal, the slope of the curve, or $\tan \phi$, must be understood in the generalized sense explained above.

The process of finding the derivative, or the equivalent process of finding the differential of the function in terms of the differential of the argument, is called *differentiation.*

11. Higher derivatives. Since the slope of the curve varies, in general, from point to point, the derivative, $f'(x)$, is itself a function of x (often called the *derived* function); the derivative of $f'(x)$ is called the *second derivative* of the given function, and is denoted by $f''(x)$, or $D_x{}^2y$, or y'' (or by $\ddot{y}$ in case the independent variable is the time); and so on for the higher derivatives.

It is also easy to define second, third, . . . *differentials,* but they are not of great importance. One matter of notation, however, should be carefully noticed, namely that d^2y/dx^2 is commonly used to denote $f''(x)$, that is $\frac{d(dy/dx)}{dx}$, and not, as one might expect $\frac{d(dy)}{(dx)^2}$.

As an example where the distinction is important, consider

$$x = \theta - \sin \theta \text{ and } y = 1 - \cos \theta,$$

where θ is the independent variable.

B. TO FIND THE DERIVATIVE WHEN THE FUNCTION IS GIVEN.

12. Formal work in differentiation. The student should be thoroughly familiar with the results of differentiating all the elementary functions. A list of the formulas which should be memorized is given below; any other formulas should be worked out as needed, or looked up in a book.

To establish these formulas, first prove the following important limits:

$$\lim_{\Delta u \doteq 0} \frac{\sin \Delta u}{\Delta u} = 1, \quad \text{and} \quad \lim_{\Delta u \doteq 0} \frac{1 - \cos \Delta u}{\Delta u} = 0,$$

provided u is in radians; and

$$\lim_{n=\infty} \left(1 + \frac{1}{n}\right)^n = e = 2.718\cdots;$$ [*]

and hence prove the formulas for differentiating the *sine* and the *logarithm*.

The proofs of the other formulas present no difficulty.

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[*] These limits having been established, it can then be shown that

$$\lim_{\Delta u \doteq 0} \frac{\sin(u + \Delta u) - \sin u}{\Delta u} = \frac{\pi}{180} \cos u, \text{ if } u \text{ is measured in degrees,}$$
$$= \cos u, \text{ if } u \text{ is measured in radians;}$$
$$\lim_{\Delta u \doteq 0} \frac{\log(u + \Delta u) - \log u}{\Delta u} = (0.4343\cdots)\frac{1}{u}, \text{ if the base is 10,}$$
$$= \frac{1}{u}, \text{ if the base is } e = 2.718\cdots.$$

The reason for choosing the radian as the unit angle, and e as the base of the "natural" system of logarithms is the simplification in the formulas for the derivatives of the sine and the logarithm which results from this choice.

RULES FOR DIFFERENTIATING THE ELEMENTARY FUNCTIONS OF A SINGLE VARIABLE.*

(The first four of these rules are the fundamental ones, from which all the others can be derived.)

The differential of a constant is zero: —

$$dk = 0.$$

The differential of the LOGARITHM to the base e of any function is one over that function, times the differential of the function: —

$$d(\log_e x) = \frac{1}{x}\,dx \qquad (e = 2.718\ldots).$$

The differential of the SINE of any function (in radians) is the cosine of that function, times the differential of the function:

$$d(\sin x) = \cos x\,dx.$$

The differential of the sum [or difference] of two functions is the differential of the first plus [or minus] the differential of the second: —

$$d(u \pm v) = du \pm dv.$$

The differential of a constant times any function is the constant times the differential of the function: —

$$d(kx) = k\,dx.\dagger$$

The differential of a function to any constant power is the exponent of the power, times the function to the power one less, times the differential of the function: —

$$d(x^n) = nx^{n-1}dx.$$

Useful special cases of this rule are: —

$$d\sqrt{x} = \frac{1}{2\sqrt{x}}\,dx; \qquad d\left(\frac{1}{x}\right) = -\frac{1}{x^2}\,dx.$$

The differential of e with a variable exponent is e with the same exponent, times the differential of the exponent: —

$$d(e^x) = e^x\,dx \qquad (e = 2.718\ldots).$$

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* All these rules remain valid when the word "derivative" is put in place of "differential," and the symbol "D" in place of "d."

† To prove this and the next five rules, let $y =$ the function, and take the logarithm of both sides before differentiating.

The differential of the product of two functions is the first times the differential of the second, plus the second times the differential of the first: —

$$d(uv) = u\,dv + v\,du.$$

The differential of the quotient of two functions is the denominator times the differential of the numerator, minus the numerator times the differential of the denominator, all divided by the denominator squared: —

$$d\left(\frac{u}{v}\right) = \frac{v\,du - u\,dv}{v^2}.$$

The differential of the cosine of any function is minus the sine of that function, times the differential of the function: —

$$d(\cos x) = -\sin x\,dx.$$ *

The differential of the tangent of any function is the secant-square of that function, times the differential of the function: —

$$d(\tan x) = \sec^2 x\,dx.$$ †

The differentials of the inverse sine, the inverse cosine, and the inverse tangent, of any function, are given by the following formulas, which the student may put into words for himself: —

$$d(\sin^{-1} x) = \frac{1}{\sqrt{1-x^2}}\,dx, \qquad (-\tfrac{1}{2}\pi \leqq \sin^{-1}x \leqq \tfrac{1}{2}\pi)$$ ‡

$$d(\cos^{-1} x) = -\frac{1}{\sqrt{1-x^2}}\,dx, \qquad (0 \leqq \cos^{-1}x \leqq \pi)$$

$$d(\tan^{-1} x) = \frac{1}{1+x^2}\,dx. \qquad (-\tfrac{1}{2}\pi \leqq \tan^{-1}x \leqq \tfrac{1}{2}\pi)$$

[To find the differential of u to the vth power, where u and v are any functions, let

$$y = u^v,$$

and take the logarithm to base e of both sides before differentiating.— Similarly, to find the differential of the logarithm of u to any base v, let

$$y = \log_v u, \text{ whence } v^y = u;$$

then differentiate both sides.]

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* Proof: $\cos x = \sin(\frac{1}{2}\pi - x)$. † Proof: $\tan x = \sin x / \cos x$.

‡ Proof: Let $y = \sin^{-1} x$, that is, $\sin y = x$; then differentiate both sides.—Similarly for the next two formulas.

The rules on these two pages suffice for the differentiation of any elementary function; they should be carefully memorized.

The differentials of the hyperbolic functions are given by the following formulas, which are also worth remembering:

$$d \sinh x = \cosh x\, dx; \quad d \cosh x = \sinh x\, dx;$$
$$d \tanh x = \operatorname{sech}^2 x\, dx;$$

hence,

$$d \sinh^{-1} x = \frac{dx}{\sqrt{x^2+1}}, \quad d \cosh^{-1} x = \frac{dx}{\sqrt{x^2-1}}, \quad d \tanh^{-1} x = \frac{dx}{1-x^2}.$$

13. Differentiation of implicit functions, and of functions expressed in terms of a parameter.

(*a*) Suppose we have an equation connecting x and y, but not giving y explicitly as a function of x; as, for example, $9x^2 + 4y^2 = 36$. In finding dy/dx in cases of this kind, instead of first solving the equation for y in terms of x, and then differentiating, it is usually better to *differentiate the equation through as it stands* (remembering that both x and y are variables); thus, in the present example we have

$$18x dx + 8y dy = 0, \text{ whence, } dy/dx = -9x/4y.$$

This result can then, if desired, be expressed wholly in terms of x, by aid of the original equation.

(*b*) Again, suppose y is given as a function of u and v, where u and v are both functions of x; as, for example, $y = u^2 + v \sin u$. Differentiating both sides by the regular rules, we have $dy = 2u du + v \cos u\, du + \sin u\, dv$, whence, collecting the terms in du and dv, and dividing by dx,

$$\frac{dy}{dx} = (2u + v \cos u)\frac{du}{dx} + (\sin u)\frac{dv}{dx}.$$

This result shows how the rate of change of y depends on the rates of change of u and v, which are supposed to be known.

(*c*) Finally, both x and y may be given as functions of a third variable, t; as, $x = F(t)$, $y = f(t)$. To every value of this auxiliary variable, or "parameter," t, there corresponds a *pair* of values of x and y, so that here again y is indirectly determined as a function of x. Of course if we can eliminate t

we shall have a single equation connecting x and y; but it is often more convenient to *keep the equations in the parameter form*. Thus, to find dy/dx, we have merely to differentiate both of the given equations: $dx = F'(t)dt$, $dy = f'(t)dt$; and then divide the second result by the first: $dy/dx = f'(t)/F'(t)$.

C. TO FIND THE DERIVATIVE WHEN THE FUNCTION ITSELF IS NOT GIVEN; SETTING UP A DIFFERENTIAL EQUATION.

14. In many cases it is required to find the rate of change of a function when the function itself is not directly given; in fact it is often easier to find the derivative of a function than it is to find the function itself.

For example, a hemispherical bowl of radius r, full of water, is being emptied through a hole in the bottom; find the rate of change of the volume of water drawn off, regarded as a function of the distance, y, between the level of the water and the center of the bowl. To compute this value directly from the definition, we notice first that the increment ΔV produced in V by an increment Δy given to y will have a value between $\pi(r^2 - y^2)\Delta y$ and $\pi[r^2 - (y + \Delta y)^2]\Delta y$; dividing either of these values by Δy, and taking the limit of the ratio $\Delta V/\Delta y$, we find at once $dV/dy = \pi\ (r^2 - y^2)$, which gives the required value of dV/dy for any value of y from $y = 0$ to $y = r$.

This process of finding the derivative directly from first principles, as the limit of the ratio of the increments, when the function itself is not given, is called "setting up a differential equation," since the result of the process is an equation between the differentials of the function and of the argument.*

Every problem of this kind is a problem in finding the *limit of the ratio of two variable quantities, each of which is approaching zero;* and in this connection the following theorems on infinitesimals are extremely useful, if not indispensable.

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* The problem of finding the relation between the quantities themselves when the relation between their differentials is known will be discussed in the next chapter.

15. Theorems on infinitesimals.

Def. Any variable quantity that approaches 0 as a limit is called an *infinitesimal.* For example, Δx, Δy, dx, dy, are infinitesimals.

The erroneous notion that an infinitesimal is a *constant* quantity which is "smaller than any other quantity, however small, and yet not zero" should be carefully avoided.

Notation. The notation $\lim x = a$, or $x \rightarrow a$ (read: "x approaches a as a limit"), means that $x = a + \epsilon$, where ϵ is a variable approaching zero. Thus a statement expressed in terms of "lim" or "$\rightarrow$" can always be translated into an *equation*, which can then be handled by the ordinary rules of algebra. The symbol $\rightarrow$ is preferable to $\doteq$ and seems likely to replace it.

Def. If α and β are infinitesimals, and $\lim (\alpha/\beta) = 0$, then α is said to be an *infinitesimal of higher order* than β.

For example, if $\Delta u = \epsilon \cdot \Delta v$, where ϵ itself approaches 0, then Δu is of higher order than Δv. Again, $1 - \cos \Delta\theta$ is of higher order than $\Delta\theta$.

If the difference between two infinitesimals is of higher order than either, then their ratio approaches 1 as a limit; and conversely, if the ratio of two infinitesimals approaches 1, then their difference is of higher order than either. Two infinitesimals having this relation may be called "**similar**" or "**equivalent**" infinitesimals.

Important examples are the following: a convex arc of a curve, and the chord of that arc, are "similar" infinitesimals. Again, $\sin \Delta x$ and $\tan \Delta x$ are both "similar" to Δx, provided Δx is in radians.

FIRST REPLACEMENT THEOREM FOR INFINITESIMALS. *In finding the limit of the ratio of two infinitesimals, either of them may be replaced by a "similar" infinitesimal, without affecting the value of the limit.*

As explained above, two infinitesimals are "*similar*": (1) if the *difference between them is of higher order than either;* or (2) if the *limit of their ratio is 1.* (Sometimes the first test is more convenient, sometimes the second.)

This theorem frequently enables us to replace a complicated infinitesimal, like $\pi(r+\Delta r)^2\Delta x$, by a simpler one, as $\pi r^2\Delta x$; *but it justifies this replacement only in the case expressly stated in the hypothesis of the theorem,* namely the case in which we are *finding the limit of a ratio.*[*] (The fallacy that "infinitesimals of higher order can *always* be neglected" should be carefully guarded against.)

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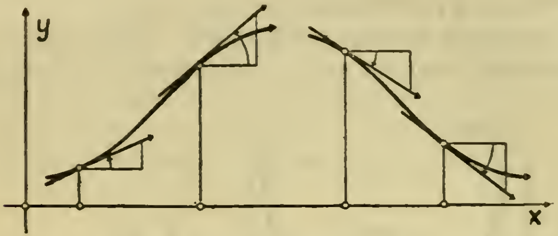
[*] A second replacement theorem for infinitesimals will be given in the chapter on Definite Integrals.

D. APPLICATIONS OF DIFFERENTIATION IN STUDYING THE PROPERTIES OF A GIVEN FUNCTION.

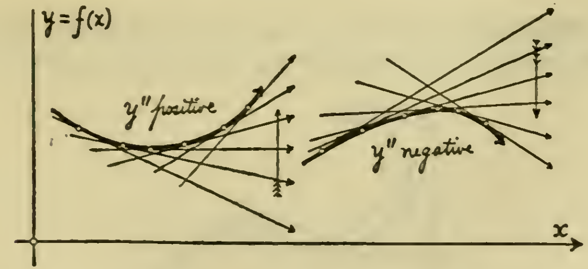
16. That a knowledge of differentiation is of fundamental importance in studying the variation of a given function is evident from the following theorems.

Let the given function be $y = f(x)$.

I. *The value of the derivative at any point shows the slope of the curve at that point.*



Hence, *if the derivative is positive* at any point, the curve is rising at that point (as we move in the positive direction along the axis); that is, *the function is increasing.* And *if the derivative is negative* at any point, the curve is falling at that point; that is, *the function is decreasing.*

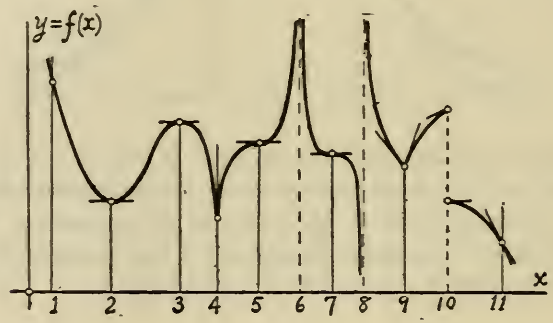


II. *If the second derivative is positive* at any point, the slope is increasing at that point, and hence *the curve is concave upward;* and *if the second derivative is negative* at any point, the slope is decreasing at that point, and hence *the curve is concave downward.*

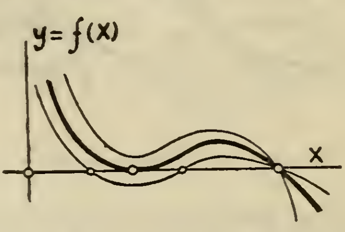
A point where the concavity changes sign is called a *point of inflexion;* at every such point, the second derivative is zero.[*]

17. Maxima and minima.—The application to problems in maxima and minima is immediate. In seeking the largest or smallest value of a given function in a given interval, we need consider only (1) the points where the slope is zero; (2) the points where the slope is infinite (or otherwise discontinuous); and (3) the end-points of the interval; for among these points the desired point will certainly be found. In most practical cases it will be a point where the slope is zero.

The conditions of the problem will usually show clearly which of these points, if any, is a maximum (or a minimum).



18. Multiple roots.—The roots, or the zeros, of a function, are the values of the argument for which the function becomes



zero. An inspection of the figure will show that any value of x for which $f(x)$ and $f'(x)$ are both zero simultaneously, will count as at least a double root.

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[*] But the second derivative may be zero at points which are not points of inflexion; for example, $y=x^4$ at $x=0$.

19. Small errors.—The following theorem is very useful in discussing the effect, on a computed value, of small errors in the data:

III. If dx is small, dy and Δy *are nearly equal.*

That is, the difference between dy and Δy can be made as small as we please, in comparison with dx, by making dx sufficiently small (except at points where dy/dx does not have a finite value).

Thus, if we wish to find approximately the error Δy produced by a small error in x, it will usually be sufficiently accurate to compute, instead of Δy, the simpler value, dy.

In problems concerning the *relative* error, dy/y, or dx/x, it is often convenient to take the logarithm of both sides of the given equation $y=f(x)$ before differentiating.

This class of problems is of great practical value.

CHAPTER III.

INTEGRATION AS THE INVERSE OF DIFFERENTIATION. SIMPLE DIFFERENTIAL EQUATIONS.

20. In many problems in pure and applied mathematics, we have given the derivative [or differential] of a function, and are required to find the function itself.

Suppose $f(x)$ [or $f(x)dx$] is the given derivative [or differential]; it is required to find a function $F(x)$ which, when differentiated, will give $f(x)$ [or $f(x)dx$]. Clearly, if one such function $F(x)$ has been found, then any function of the form $F(x)+C$, where C is any constant, will have the same property.

DEFINITION.—*Any function $F(x)$ whose differential is $f(x)dx$ is denoted by*

$$\int f(x)dx,$$

read: **an integral** *of $f(x)dx$.* The process of finding an integral of a function is called *integration,* or the *inverse of differentiation.*

If $F(x)$ is any particular integral of $f(x)dx$, then every integral of $f(x)dx$ can be expressed in the form $F(x)+C$, where C is a constant, called the *constant of integration.*

It can be shown that every continuous function has an integral; but this integral may not (in general, will not) be expressible in terms of the elementary functions.[*]

Most of the functions that occur in practice can, however, be integrated in terms of elementary functions, by the aid of a table of integrals, such as B. O. Peirce's well-known table of integrals. The entries in such a table can be verified by differentiation.

21. Formal work in integration.—The time devoted to the formal work of integration should not be longer than is necessary to give the student a reasonable degree of expertness in the use of the tables.

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[*] In such cases, an approximate expression for the integral may be obtained by infinite series.

The following integration formulas should be memorized; they are derived immediately from the corresponding formulas for differentiation.

$$\int cudx = c\int udx; \quad \int (u + v + \cdots)dx = \int udx + \int vdx + \cdots;$$

$$\int x^n dx = \frac{x^{n+1}}{n+1} \text{ (provided } n \neq -1\text{)};$$

(in words: an integral of any function raised to a constant power, $\neq -1$, times the differential of that function, is equal to the function raised to a power one greater, divided by the new exponent);

$$\int \frac{dx}{x} = \log_e x; \qquad \int e^x dx = e^x;$$

$$\int \sin x\, dx = -\cos x; \quad \int \cos x\, dx = \sin x; \quad \int \sec^2 x\, dx = \tan x;$$

$$\int \frac{dx}{\sqrt{1-x^2}} = \sin^{-1} x, \text{ or } -\cos^{-1} x; \qquad \int \frac{dx}{1+x^2} = \tan^{-1} x.$$

The constant of integration must be supplied in each case.

A large number of integrals can be brought under the form $\int x^n dx$ by a simple transformation. For example,

$$\int \cos^3 x\, dx = \int \cos^2 x \cos x\, dx = \int (1 - \sin^2 x) \cos x\, dx$$
$$= \int \cos x\, dx - \int \sin^2 x \cos x\, dx = \int \cos x\, dx - \int (\sin x)^2 d(\sin x)$$
$$= \sin x - (\sin x)^3/3.$$

Similarly for any odd power of the sine or cosine.

The following integrals are also important, though it is not worth while to memorize them when a table is at hand:

$$\int \sin^2 x dx = \tfrac{1}{2}(x - \sin x \cos x); \quad \int \cos^2 x dx = \tfrac{1}{2}(x + \sin x \cos x);$$

$$\int \frac{dx}{\cos x} = \log_e \tan\left(\frac{\pi}{4} + \frac{x}{2}\right) = \tfrac{1}{2}\log_e \frac{1+\sin x}{1-\sin x}; \quad \int \frac{dx}{\sin x} = \log_e \tan \frac{x}{2};$$

$$\int \sinh x\, dx = \cosh x; \quad \int \cosh x\, dx = \sinh x; \quad \int \operatorname{sech}^2 x dx = \tanh x.$$

22. Among the other formulas of integration, the following are perhaps the ones that occur most often in practice; they are inserted here for reference, and especially to illustrate the usefulness of the hyperbolic functions.

$$\int \frac{dx}{a^2 + x^2} = \frac{1}{a} \tan^{-1} \frac{x}{a},$$

$$\int \frac{dx}{a^2 - x^2} = \frac{1}{2a} \log_e \frac{a + x}{a - x} = \frac{1}{a} \tanh^{-1} \frac{x}{a},$$

$$\int \frac{dx}{x^2 - a^2} = \frac{1}{2a} \log_e \frac{x - a}{x + a} = -\frac{1}{a} \coth^{-1} \frac{x}{a},$$

$$\int \frac{dx}{\sqrt{a^2 - x^2}} = \sin^{-1} \frac{x}{a}, \quad \text{or} \quad = -\cos^{-1} \frac{x}{a},$$

$$\int \frac{dx}{\sqrt{x^2 + a^2}} = \log_e (x + \sqrt{x^2 + a^2}), \quad \text{or} \quad = \sinh^{-1} \frac{x}{a},$$

$$\int \frac{dx}{\sqrt{x^2 - a^2}} = \log_e (x + \sqrt{x^2 - a^2}), \quad \text{or} \quad = \cosh^{-1} \frac{x}{a},$$

$$\int \sqrt{a^2 - x^2}\, dx = \tfrac{1}{2} \left[x\sqrt{a^2 - x^2} + a^2 \sin^{-1} \frac{x}{a} \right],$$

$$\int \sqrt{x^2 + a^2}\, dx = \tfrac{1}{2} [x\sqrt{x^2 + a^2} + a^2 \log_e (x + \sqrt{x^2 + a^2})],$$

$$\text{or} = \frac{1}{2} \left[x\sqrt{x^2 + a^2} + a^2 \sinh^{-1} \frac{x}{a} \right],$$

$$\int \sqrt{x^2 - a^2}\, dx = \tfrac{1}{2} [x\sqrt{x^2 - a^2} - a^2 \log_e (x + \sqrt{x^2 - a^2})],$$

$$\text{or} = \frac{1}{2} \left[x\sqrt{x^2 - a^2} - a^2 \cosh^{-1} \frac{x}{a} \right].$$

23. **Methods of Integration.** Among the methods by which a given integral may be reduced to a form in the tables (or an integral in the table to one of the fundamental forms), the most important are (1) the method of substitution and (2) the method of integration by parts.

In the *method of substitution*, the given integral, $\int f(x)dx$, is expressed wholly in terms of some new variable y (and dy), in the hope that the new integral may be easier to handle than the old one. The substitutions which are most likely to be useful are the following:

(*a*) $y=$ any part of the given expression whose differential occurs as a factor; $y=x^k$; $y=1/x$; $y=\sin x$; $y=\cos x$; $y=\tan(x/2)$.

(*b*) $x=a\sin y$, or $=a\tan y$, or $=a\sec y$, in expressions involving $\sqrt{a^2-x^2}$, or $\sqrt{a^2+x^2}$, or $\sqrt{x^2-a^2}$, respectively.

But much can be done without formal substitution of a new letter, if one remembers that the "x" in the formulas of integration may stand for any function.

The *method of integration by parts* is an application of the formula

$$\int u\,dv=uv-\int v\,du.$$

Take as dv a part of the given expression which can be readily integrated; on applying the formula, the new integral may be simpler than the old one.

The student should be practiced in both of these methods.

24. Simple differential equations. In a large number of problems in pure and applied mathematics, it is possible to write down an expression involving the rate of change of a desired function more readily than to write down the expression for the function itself. (Compare Chap. II, B.) In other words, it is often easier to write down a relation between the differentials of two variables than to write down the relation between the variables themselves. Such a relation connecting the differentials of two or more quantities, is called a *differential equation*, and any function which satisfies the equation, when substituted therein, is called a *solution* of the equation.

Every such problem, then, breaks up into two parts: (1) setting up the differential equation; (2) solving that equation.

The first part of the problem has already been treated in Chap. II, B. This part of the problem is too apt to be neglected in elementary courses; there is scarcely anything that develops real appreciation of the power of the calculus more effectively than practice in setting up for one's self the differential equations for various physical phenomena.

As to the second part of the problem, namely, the *solution* of the differential equation, the general plan is to reduce the given equation, by more or less ingenious devices, to the form $dy = f(x)dx$, or $y = \int f(x)dx$, and then to complete the solution, if possible, by the aid of a table of integrals. In a technical sense, the differential equation is said to be "solved" when it is thus reduced to a simple "quadrature"; that is, to a single integration.

The solution of a differential equation of the nth order, that is, an equation involving the nth derivative, will contain n arbitrary constants; to determine these constants, n conditions connecting $x, y, y' \ldots, y^{(n)}$ must be known (the "initial" or "auxiliary" conditions of the problem).

25. The general discussion of differential equations is too large and too difficult a topic to find a place in a first course in the calculus, but two, at least, of the simpler equations are so important that their solution should be given, as an exercise in integration.

These equations are the following:

$$(1) \qquad \frac{dy'}{dt} + n^2 y = 0, \text{ where } y' = \frac{dy}{dt}.$$

The solution is

$$y = C_1 \sin(nt + C_2) \text{ or, } y = C_3 \sin nt + C_4 \cos nt,$$

where the C's are arbitrary constants.

$$(2) \qquad \frac{dy'}{dt} - n^2 y = 0, \text{ where } y' = \frac{dy}{dt}.$$

The solution is

$$y = C_1 \sinh(nt + C_2), \text{ or, } y = C_3 e^{nt} + C_4 e^{-nt},$$

where the C's are arbitrary constants.

The method of obtaining these results, rather than the results themselves, should be remembered: namely, multiply through by dy, noting that $dy/dt = y'$, and integrate each term, getting $\frac{1}{2}y'^2 + \frac{1}{2}n^2y^2 = C$; then replace y' by dy/dt, "separate the variables," and integrate again. By a similar method, any equation of the form $dy'/dt + f(y) = 0$ can be solved, if we can integrate $f(y)\,dy$.

26. Another very important differential equation is the equation for "damped vibration":

$$\frac{dy'}{dt} + 2b\frac{dy}{dt} + a^2y = 0, \text{ where } y' = \frac{dy}{dt}.$$

The solution is given here for reference:

Case 1. If $a^2 - b^2 > 0$, let $m = \sqrt{a^2 - b^2}$; then

$$y = C_1e^{-bt}\sin(mt + C_2),$$

$$\text{or } y = [C_3\sin(mt) + C_4\cos(mt)]e^{-bt}.$$

Case 2. If $a^2 - b^2 = 0$,

$$y = e^{-bt}(C_1 + C_2t).$$

Case 3. If $a^2 - b^2 < 0$, let $n = \sqrt{b^2 - a^2}$; then

$$y = C_1e^{-bt}\sinh(nt + C_2),$$

$$\text{or } y = C_3e^{-(b+n)t} + C_4e^{-(b-n)t}.$$

CHAPTER IV.

INTEGRATION AS THE LIMIT OF A SUM. DEFINITE INTEGRALS.

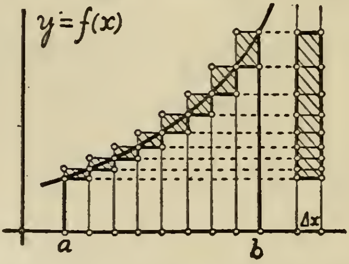
27. The limit of a sum. Many problems in pure and applied mathematics can be brought under the following general form:

Given, a continuous function, $y=f(x)$, *from* $x=a$ *to* $x=b$. *Divide the interval from* $x=a$ *to* $x=b$ *into* n *equal parts, of length* $\Delta x=(b-a)/n$.* *Let* $x_1, x_2, x_3, \ldots x_n$ *be values of* x, *one in each interval; take the value of the function at each of these points, and multiply by* Δx; *then form the sum:*

$$f(x_1)\Delta x+f(x_2)\Delta x+\cdots+f(x_n)\Delta x.$$

Required, the limit of this sum, as n *increases indefinitely, and* $\Delta x \doteq 0$.

This problem may be interpreted geometrically as the problem of finding the area under the curve $y=f(x)$, between the ordinates $x=a$ and $x=b$; each term of the sum represents the area of a rectangle whose base is Δx and whose altitude is the height of the curve at one of the points selected. It is easily seen that the difference between the sum of the rectangles and the area of the curve is less than a rectangle



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* It is not necessary that the parts be equal, provided the largest of them approaches zero when n is made to increase indefinitely.

whose base is Δx and whose altitude is constant. This difference approaches zero as $\Delta x \doteq 0$; therefore the sum of the rectangles approaches the area of the curve as a limit.

In this way, or by an analytic proof, it is shown that the limit of the sum in question always exists. The problem then is, to find the value of this limit.

The value of the limit can always be obtained by the following fundamental theorem, whenever an integral of the given function $f(x)$ can be found.

FUNDAMENTAL THEOREM OF SUMMATION. *If* $x_1, x_2, \cdots x_n$ *are values of* x *ranging from* $x = a$ *to* $x = b$, *as in the statement of the general problem above, then*

$$\lim_{\Delta x \doteq 0} [f(x_1)\Delta x + f(x_2)\Delta x + \cdots + f(x_n)\Delta x] = F(b) - F(a),$$

where

$$F(x) = \int f(x)dx$$

is any function whose derivative is the given function $f(x)$.

The proof of this remarkable theorem is best given by showing that the right hand side of the equation, as well as the left, is equal to the area under the curve from $x = a$ to $x = b$; to do this, consider the area from $x = a$ to a variable point $x = x$, and find the rate of change of this area regarded as a function of x; hence find the area itself as a function of x, determine the constant of integration in the usual way, and then put $x = b$ in the result.

DEFINITION. *The limit of a sum of the kind described above is called the* definite integral *of* $f(x)dx$ *from* $x = a$ *to* $x = b$, *and is denoted by*

$$\lim_{n \doteq \infty} \sum_{i=0}^{i=n} f(x_i)\Delta x, \quad \text{or} \int_{x=a}^{x=b} f(x)dx.$$

The function obtained by the inverse of differentiation is called, for distinction, an *indefinite* integral. By the fundamental theorem just stated, the definite integral is equal to the difference between two values of the indefinite integral:

$$\int_{x=a}^{x=b} f(x)dx = \Big[\int f(x)dx\Big]_{x=b} - \Big[\int f(x)dx\Big]_{x=a}.$$

The double use of the term "integration"—meaning in one case anti-differentiation, and in the other case finding the limit of a sum—and the fundamental theorem connecting these two distinct concepts, should be made thoroughly clear.*

The concept of the definite integral is the most useful concept in the application of the calculus, and the study of problems which can be formulated as definite integrals may well occupy one third of the time of a first course.

For example, problems in areas, volumes, surfaces, length of arc, center of gravity, moments of inertia, center of fluid pressure, etc. *Many of these problems require two applications of the fundamental theorem.*

28. Properties of definite integrals. From the definition of the definite integral we have at once:

$$\int_a^b f(x)dx = -\int_b^a f(x)dx;$$

$$\int^c f(x)dx + \int_c^b f(x)dx = \int_a^b f(x)dx;$$

and, by the aid of a figure, the *Mean Value theorem:*

$$\int_a^b F(x)f(x)dx = F(X)\int_a^b f(x)dx,$$

where X is some (unknown) value of x between a and b, and $F(x)$ and $f(x)$ are any continuous functions, provided $f(x)$ *does not change sign* from $x=a$ to $x=b$.

We have also the following important theorem on *change of variable:*

In evaluating the integral

$$\int_{x=a}^{x=b} f(x)dx,$$

if x is a function of a new variable t, we may replace $f(x)dx$ by its value in terms of t and dt, and replace $x=a$ and $x=b$

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* The use of the term in the sense of summation was historically the earlier, and the symbol $\int$ is the old English "long s," the first letter of "sum."

by the corresponding values $t=\alpha$ and $t=\beta$, without altering the value of the integral, provided that thoroughout the interval considered there is one and only one value of x for every value of t, and one and only one value of t for every value of x.

29. All problems leading to a definite integral are problems in finding the limit of a sum, each term of which is approaching zero, while the number of terms is increasing indefinitely. Whenever a function $f(x)$ can be found, such that all terms of the sum are obtained by substituting successively x_1, x_2, etc., in the expression $f(x)dx$, then the formulation of the problem as a definite integral is immediately obvious. The separate terms of the sum, of which $f(x_k)dx$ is a type, are called *elements.*

Thus, in finding the area under a curve, an obvious element of area is the rectangle ydx; if the curve revolves about the x-axis, the element of volume of the solid thus generated is the cylinder πy^2dx. Here y must be expressed as a function of x before the integration can be completed. Again, in polar coördinates, the element of area is the sector, $\frac{1}{2}r^2d\theta$, where r must be a known function of θ.

In many cases, however, the proper function is not so immediately obvious. In such cases, the following theorem is of great service:

SECOND REPLACEMENT THEOREM FOR INFINITESMALS (THEOREM OF DUHAMEL). *In finding the limit of a sum of positive terms, each of which approaches zero while the number of terms increases indefinitely, any term may be replaced by a "similar" term without affecting the value of the limit. Two variables* α *and* β *are called "similar" if*

$$(1) \qquad \lim\frac{\alpha}{\beta}=1, \quad \textit{or} \quad \textit{if } (2) \ \lim\frac{\alpha-\beta}{\alpha}=0.$$

For example, let us find the weight of a rod whose density, w, and cross-section, A, are both functions of x. The "true element" of weight, ΔW, corresponding to a given length Δx, will certainly lie between the values $w'A'\Delta x$ and $w''A''\Delta x$, where

w', A' are the smallest values, and w'', A'' the largest values of w and A within the interval from $x = x$ to $x = x + \Delta x$; but either of these extreme values may be replaced by the simpler value $wA\Delta x$, where w, A are the values of w and A at the *beginning* of the interval, for,

$$\lim \frac{w'A'\Delta x}{wA\Delta x} = \lim \frac{w''A''\Delta x}{wA\Delta x} = 1.$$

Hence, ΔW itself, which lies between these extremes, can be replaced by $wA\Delta x$, which is therefore the required "differential element" of weight.* The total weight of the rod, from $x = a$ to $x = b$, is then equal to the definite integral

$$\int_{x=a}^{x=b} wA dx;$$

where w and A must of course be expressed as functions of x before the integration can be completed.

In justifying replacements of this kind by Duhamel's theorem, sometimes the first test is more convenient, sometimes the second. When once the common replacements have been justified, the use of the theorem in practice rapidly becomes almost intuitive.

30. Approximate methods of integration.—If the function $f(x)$ is given only empirically, the theorem on evaluating the definite integral by purely mathematical means cannot be applied. In such cases, an approximate value of the definite integral

$$\int_{x=a}^{x=b} f(x) dx$$

may be found by plotting the curve $y = f(x)$ on squared paper, and estimating the area by *counting squares* (and fractions of squares).

Another method of approximation is by *Simpson's Rule:*

---

* When x is the independent variable, it is immaterial whether we write Δx or dx.

Divide the area into n panels, where n is *even*, and number the ordinates from 1 to $n+1$; then, if Δx is the width of each panel,

Area $= \frac{1}{3}\Delta x$ (first ordinate + last ordinate
+ twice the sum of the other odd ordinates
+ four times the sum of the even ordinates).

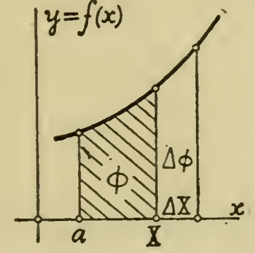
The instrument known as a *planimeter* provides a mechanical means of integration, used especially in measuring the areas of indicator cards.

Another and very important method of approximation is by the use of *series;* see the next chapter.

31. Definite Integral as a function of its upper limit.—If X is a variable, the definite integral

$$\int_{x=a}^{x=X} f(x)dx$$

represents the area under the curve $y=f(x)$ from $x=a$ to the variable ordinate $x=X$, and is therefore a function of X, say $\phi(X)$. By applying the definition of derivative to this function, it is easy to see from the figure that $\phi'(X)=f(X)$:



$$\frac{d}{dX}\int_{x=a}^{x=X} f(x)dx = f(X).$$

Thus $\phi(X)$ is one of the indefinite integrals of $f(X)$.

Any indefinite integral which cannot be expressed in terms of known functions can always be written as a definite integral regarded as a function of its upper limit, and its value, for any given value of the argument, can then be found by one of the methods of approximate integration.

The elliptic integrals, the most important of which are

$$\int_{\theta=0}^{\theta=\phi} \frac{d\theta}{\sqrt{1-(k^2)\sin^2\theta}} \quad \text{and} \quad \int_{\theta=0}^{\theta=\phi} \sqrt{1-(k^2)\sin^2\theta}\, d\theta,$$

are handled in this way, by the method of expansion in series. The student should be made familiar with the construction and use of tables of the elliptic integrals.

In such tables, k^2 is usually expressed in the form $\sin^2 a$, which emphasizes the fact that $k^2 \leqq 1$.

CHAPTER V.

APPLICATIONS TO ALGEBRA: EXPANSION IN SERIES; INDETERMINATE FORMS.

Note.—This chapter may be taken, if preferred, immediately after the chapter on differentiation. It is in reality an extension of the "formal work" of that chapter, since it deals with changes in the *form* of algebraic expressions.

32. Taylor's theorem.—It is often desirable to obtain an approximate expression for a given function, in the neighborhood of a given point $x=a$, in the form of a series arranged according to ascending powers of $x-a$, with constant coefficients. For values of x near to a, the higher powers of $x-a$ will then become negligible.

The most convenient theorem for this purpose is the following:

TAYLOR'S THEOREM. *If $f(x)$ is continuous, and has derivatives through the $(n+1)$st, in the neighborhood of a given point $x=a$, then, for any value of x in this neighborhood,*

$$f(x)=f(a)+\frac{f'(a)}{1!}(x-a)+\frac{f''(a)}{2!}(x-a)^2+\cdots$$
$$+\frac{f^n(a)}{n!}(x-a)^n+\frac{f^{n+1}(X)}{(n+1)!}(x-a)^{n+1},$$

where X is some unknown quantity between a and x. The last term,

$$R=\frac{f^{n+1}(X)}{(n+1)!}(x-a)^{n+1},$$

is the *error* committed if we stop the series with the term in $(x-a)^n$, and the formula is useful only when this error becomes smaller and smaller as we increase the number of terms.

This form for the "remainder" R is easily remembered since it differs from the general term of the series only by the fact that the derivative in the coefficient of the power of $(x-a)$ is taken for $x=X$ instead of for $x=a$.* (There are also other forms of the remainder which are sometimes useful.)

33. The special case where $a=0$ is called **Maclaurin's Theorem**:

$$f(x)=f(0)+\frac{f'(0)}{1!}x+\frac{f''(0)}{2!}x^2+\cdots+\frac{f^n(0)}{n!}x^n+\frac{f^{n+1}(X)}{(n+1)!}x^{n+1},$$

where X is some unknown quantity between 0 and x.

34. Another special case, obtained by putting $n=0$, gives

$$f(x)-f(a)=f'(X)(x-a),$$

where again X is some unknown quantity between a and x. This theorem is called the **Law of the Mean**, and is of great importance in the theoretical development of the subject.

35. If the error-term in Taylor's Theorem approaches zero as n increases, the formula becomes a convergent infinite series, called the **Taylor's series** for the given function, about the given point $x=a$.

The series with which the student should be especially familiar are the following:

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* The simplest proof of this theorem is by means of integration. For example, for the case $n=2$, we have

$$\int_a^x f''(t)dt=f'''(X)(x-a),$$

where X is some (unknown) constant between a and x (as is evident from a figure); but also

$$\int_a^x f'''(t)dt=f''(x)-f''(a),$$

by the fundamental theorem; so that

$$f''(x)-f''(a)=f'''(X)(x-a).$$

Integrating this equation twice between the limits $x=a$ and $x=x$, remembering that $f''(a)$ and $f'''(X)$ are constants, we have at once:

$$f'(x)-f'(a)-f''(a)(x-a)=f'''(X)\tfrac{1}{2}(x-a)^2,$$
$$f(x)-f(a)-f'(a)(x-a)-f''(a)\tfrac{1}{2}(x-a)^2=f'''(X)\tfrac{1}{2}\tfrac{1}{3}(x-a)^3.$$

Binomial series:

$$(1+x)^m = 1 + mx + \frac{m(m-1)}{2\,!}x^2 + \frac{m(m-1)(m-2)}{3\,!}x^3 + \cdots,$$

provided $|x| < 1$.

Sine series:

$$\sin x = x - \frac{x^3}{3\,!} + \frac{x^5}{5\,!} - \frac{x^7}{7\,!} + \cdots \quad (x \text{ in radians}).$$

Cosine series:

$$\cos x = 1 - \frac{x^2}{2\,!} + \frac{x^4}{4\,!} - \frac{x^6}{6\,!} + \cdots \quad (x \text{ in radians}).$$

Exponential series:

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \cdots.$$

Next in importance are the series for log $(1+x)$, $\tan^{-1} x$, $\sinh x$, and $\cosh x$.

From these series we have the following important approximations, when x is small:

$$\sqrt{1+x} = 1 + \frac{1}{2}x - \cdots, \quad \frac{1}{1+x} = 1 - x + \cdots, \quad \frac{1}{\sqrt{1+x}} = 1 - \frac{1}{2}x + \cdots,$$

$$\sin x = x - \cdots, \quad \cos x = 1 - \cdots, \text{ etc.}$$

An important special case of the binomial series is the geometric series:

$$\frac{1}{1-x} = 1 + x + x^2 + x^3 + \cdots, \quad \text{provided } |x| < 1.$$

36. The student should also understand the comparison test, and the test-ratio test, for the convergence of an infinite series, and the following theorem on *alternating* series: If the terms of a series are alternately positive and negative, each being numerically less than or equal to the preceding, and if the nth term approaches zero as n increases, then the series is convergent, and the error made by breaking off the series at any given term does not exceed numerically the value of the last term retained.

Further, *a power series can be differentiated or integrated term by term, within the interval of convergence.*

37. Indeterminate forms.—The evaluation of indeterminate forms can often be facilitated by the use of the following theorem, in which $f(x)$ and $F(x)$ are functions which possess derivatives at a given point $x=a$.

Theorem of indeterminate forms. If $f(x)$ and $F(x)$ both approach zero, or both become infinite, when x approaches a, then

$$\lim_{x \doteq a}\left[\frac{f(x)}{F(x)}\right]=\lim_{x \doteq a}\left[\frac{f'(x)}{F'(x)}\right].$$

The second limit may often be easier to evaluate than the first.

The student should thoroughly understand the meaning of indeterminate forms, for which the common symbols $\frac{0}{0}$, 1^∞, etc., are merely a suggestive short-hand notation.

Thus, "0/0" means that we are asked to find the limit of a function $y=f(x)/F(x)$, when $f(x)$ and $F(x)$ both approach zero. Now the change in $f(x)$ alone would tend to decrease y numerically, while the change in $F(x)$ alone would tend to increase y; hence we cannot tell, without further investigation, what the combined effect of both changes, taking place simultaneously, will be.

Again, the symbol 1^∞ means that we are asked to find the limit of a function $y=f(x)^{F(x)}$, when $f(x)$ approaches 1 and $F(x)$ becomes infinite. Now the change in $f(x)$ alone would tend to make y approach 1, while the change in $F(x)$ alone would tend to make y recede from 1; hence we cannot tell, without further investigation, what the combined effect will be.

The student should thoroughly master in this way the meaning of all the seven types of indeterminate forms, namely,

$$\frac{0}{0},\ \frac{\infty}{\infty},\ 0\cdot\infty,\ 0^0,\ 1^\infty,\ \infty^0,\ \infty-\infty.$$

The cases involving exponents are best treated by first finding the limit of the logarithm of y, from which the limit of y

can then be obtained. The form $0 \cdot \infty$, or $y = f(x) \cdot F(x)$, can be written as $y = \frac{f(x)}{1/F(x)}$, or $y = \frac{F(x)}{1/f(x)}$, which then comes under one of the first two forms. The last form, $\infty - \infty$, is usually best handled by the method of series.

Before applying the theorem of indeterminate forms, one should, of course, try first to find the required limit by a simple algebraic transformation, if possible.

CHAPTER VI.

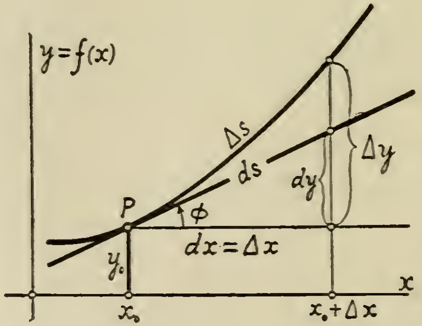
APPLICATIONS TO GEOMETRY AND MECHANICS.

In all applications to geometry, in which a curve is represented by an equation connecting x and y, the *scales on the x and y axes must be equal* (compare §3, footnote).

38. Tangent and normal.—The equation of the tangent at any point (and hence the equation of the normal) can be written down at once when we know the slope and the coördinates of the point of contact.

Again, to find the *subtangent* or *subnormal* at any point, we have simply to find the ordinate and the slope at that point, and then solve a right triangle.

39. Differential of arc. If s = length of arc of the curve $y=f(x)$, measured from some fixed point A of the curve, then s, like y, is a function of x, and we may ask what is the rate of change of s with respect to x, that is, what is the value of ds/dx. Now $ds/dx = \lim\,(\Delta s/\Delta x)$, and in finding this limit we may replace the arc Δs by its chord, $\sqrt{(\Delta x)^2+(\Delta y)^2}$; hence $ds/dx = \lim \sqrt{1+(\Delta y/\Delta x)^2} = \sqrt{1+(dy/dx)^2}$, or



$$ds = \sqrt{(dx)^2+(dy)^2},$$

as indicated in the figure. This formula, and the corresponding relations

$$dx = ds \cos \phi, \quad dy = ds \sin \phi,$$

are important, and are readily recalled to mind by the figure.

In the case of a circle of radius r, if $d\theta =$ the angle at the center, subtended by the arc ds, then

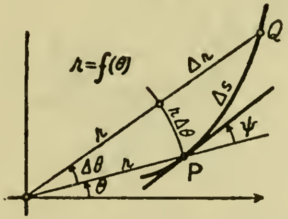
$$ds = r d\theta,$$

provided the angle is measured in radians.

40. Again, in case of a curve whose equation is given in polar coordinates, $r = f(\theta)$, we see at once from the figure, by the aid of the replacement theorem, that

$$ds = \sqrt{(dr)^2 + (rd\theta)^2} \quad \text{and} \quad \tan \psi = \frac{rd\theta}{dr},$$

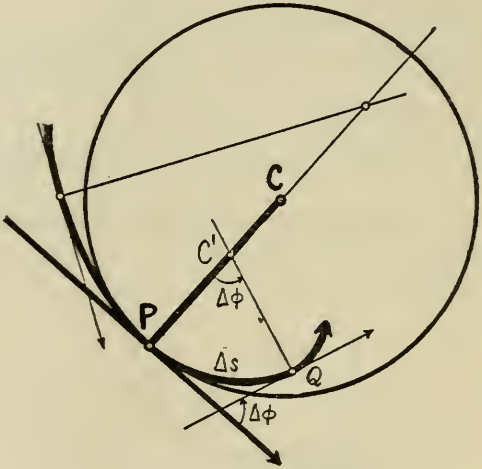
where ψ is the angle which the tangent makes with the radius vector produced.



41. **Radius of Curvature.**—Consider the normal to a given curve at a given point, P, and also the normal at a neighboring point, Q. These two normals will intersect at some point C' on the concave side of the curve; and as Q approaches P, along the curve, this point C' will (in general) approach a definite position C as a limit. The circle described with a center at this point C and radius equal to CP will fit the given curve more closely, in the neighborhood of the point P, than does any other circle. This circle is called the *osculating circle,* or the circle of curvature, at the point P; its center C is called the *center of curvature,* and its radius CP is called the *radius of curvature,* at the point P.

The radius of curvature may thus be taken as a measure of the flatness or sharpness of the curve; the smaller the radius of curvature, the sharper the curve.

The length of the radius of curvature, R, at any point P is most readily found as follows: In the triangle $PC'Q$, we have $C'P/PQ = \sin Q/\sin \Delta\phi$, where $\Delta\phi$ is the angle between the normals (or between the tangents) at P and Q. Therefore $R = \lim C'P = \lim$ (chord $PQ/\sin \Delta\phi$) $\sin Q$; or, replacing the chord by the arc Δs, and $\sin \Delta\phi$ by $\Delta\phi$, and noticing that Q is approaching 90°, so that $\lim \sin Q = 1$, we have $R = \lim (\Delta s/\Delta\phi)$, or,



$$R = \frac{ds}{d\phi}.$$

This important formula is readily recalled to mind from the figure, if one thinks of the arc Δs as approximately a circular arc.

To express R in terms of x and y, we have only to remember that $ds = \sqrt{(dx)^2 + (dy)^2} = \sqrt{1 + y'^2}dx$, and $\tan \phi = dy/dx = y'$, whence $d\phi = y''dx/(1 + y'^2)$; then

$$R = \frac{(1+y'^2)^{\frac{3}{2}}}{y''}$$

Def. The *curvature* of a curve at a point is defined as the rate at which the angle ϕ is changing with respect to the length of arc s; that is,

$$\text{curvature} = \frac{d\phi}{ds} = \frac{1}{R}.$$

If the slope of the curve is small, the curvature is approximately equal to y''.

Def. The locus of the center of curvature is called the *evolute* of the curve.

The normals to the given curve are tangent to the evolute, and the given curve may be traced by unwinding a string from the evolute.

42. Velocity and acceleration.—Consider a particle moving along a *straight line.* Its distance from the origin is a function of the time:

$$x = F(t).$$

The *velocity* of the particle is the *rate of change of its distance:*

$$v = dx/dt = F'(t) = x'.$$

The velocity will be positive or negative, according as the particle is moving forward or backward along the line.

The *acceleration* of the particle is the *rate of change of its velocity:*

$$A = dv/dt = F''(t) = x''.$$

The acceleration will be positive or negative according as the velocity is increasing or decreasing (algebraically).

If a particle is moving along a *plane curve,* we must consider the *components* of its motion along two fixed axes. The components of acceleration along the x- and y-axes are x'' and y''; the components of acceleration along the tangent and normal are dv/dt and v^2/R, respectively, where $v = \sqrt{x'^2 + y'^2}$ = the path velocity, and R = the radius of curvature.

It should be carefully noticed that dv/dt is not the whole acceleration, but only that component of the acceleration which lies along the tangent.

The importance of this application in problems in mechanics is obvious.

Note.—As explained in the preface of this report, these pages are intended merely to give a résumé of the working principles of the calculus with which the student should be perfectly familiar after having taken a course in this subject. *The main part of the work of such a course should be problems done by the students—each problem being solved on the basis of the small number of fundamental theorems here mentioned.*

DISCUSSION.

Professor Chas. O. Gunther: It seems to me that in this report some mention should be made of imaginary and complex quantities. A little knowledge of these quantities can, for instance, be utilized to good advantage by applying it to that part of the calculus known as integration. In fact, integration can be simplified to the extent of eliminating the usual "reduction formulæ" and rendering the use of tables of integrals unnecessary.

As found in text-books in general, there are three cases for which the expression

$$dy = \cos^h\theta \sin^k\theta d\theta \qquad (1)$$

can be easily integrated. Two of these cases include fractional values for h and k. All other cases in which h and k are integers can either directly, or by means of a single imaginary trigonometric substitution ($\tan\theta = i \sin\alpha$, in which α is an imaginary quantity), be reduced to one or more of the three cases just referred to.

The general binomial differential expression

$$dy = x^m(a + bx^n)^{p/q}dx \qquad (2)$$

is only another form of (1) since $\sqrt{a + bx^n}$ can always be represented by one of the three sides of a right triangle and therefore expressed as a trigonometric function of one of the acute angles of the triangle.

To make this transformation the student must know the relation between the hypotenuse and the two sides of a right triangle, the values of the trigonometric functions of an angle in terms of the sides of a right triangle, and the rules for differentiation.

Differential expressions involving trinomial surds may be rationalized in a similar manner.

The expressions

$$\frac{d^ny}{dx^n} = e^{ax} \cos bx, \qquad (3)$$

$$\frac{d^ny}{dx^n} = e^{ax} \sin bx, \qquad (4)$$

may be integrated with great facility if complex quantities are employed, because $e^{ax}\cos bx$ and $e^{ax}\sin bx$ are the rectangular components of a vector whose modulus is e^{ax} and whose argument is bx. The integrals of (3) and (4) are found from the integral of

$$\frac{d^n z}{dx^n} = e^{(a+ib)x}, \tag{5}$$

in which z is a complex variable of the form $y + iy$. The integral of (5) is readily found to be

$$z = \frac{e^{(a+ib)x}}{(a+ib)^n} + \dot{C}_{n-1}x^{n-1} + \cdots + \dot{C}_1 x + \dot{C}_0, \tag{6}$$

in which $\dot{C}_{n-1}, \cdots \dot{C}_1, \dot{C}_0$, are constants of the form $\dot{C} = C + iC$. Equation (6) may be written

$$z = \frac{e^{ax}}{(a^2+b^2)^{n/2}} e^{i(bx - n \tan^{-1} b/a)} + \dot{C}_{n-1}x^{n-1} + \cdots + \dot{C}_1 x + \dot{C}_0. \tag{7}$$

The integral of (3) is the real part of (7) and the integral of (4) is the imaginary part of (7) divided by i.

Again in differential equations we find the linear equations

$$\frac{dy}{dx} + ay = b \cos nx, \tag{8}$$

$$\frac{dy}{dx} + ay = b \sin nx, \tag{9}$$

and their solutions can be obtained from the solution of the equation

$$\frac{dz}{dx} + az = be^{inx}, \tag{10}$$

in which $z = y + iy$.

The foregoing illustrates a few of the applications of complex and imaginary quantities, and includes a first treatment of hyperbolic functions as trigonometric functions of imaginary quantities.

Some little consideration should also be given to the complex and imaginary branches of certain curves, as for example, the circle, the ellipse, and the hyperbola. It should be noted that the equation of the circle $x^2 + y^2 = a^2$ is also the equation of an imaginary hyperbola for values of $x > a$ and $< -a$. This is important, since of the three forms of binomial surds $\sqrt{a^2 - x^2}$, $\sqrt{a^2 + x^2}$, $\sqrt{x^2 - a^2}$, the first is obtained from the equation of the circle $x^2 + y^2 = a^2$, and the latter two from the equation of the hyperbola $x^2 - y^2 = a^2$; but all three are obtained from the equation of the circle if imaginary quantities are made use of.

Professor J. E. Boyd: I want to emphasize everything Professor Gunther just said about the use of complex quantities. We cannot derive a formula for an eccentrically loaded long column without the use of them; we cannot make alternating current calculations without them. A student might as well learn how to use them. I endorse what he says about the use of integral tables in teaching calculus. Our professors in calculus last year adopted a book that advised the use of tables. This year a book of the other type was selected. We did not use the tables any more than was absolutely necessary and found the result satisfactory. The student does not need tables often, except to make use of the several transformations.

Professor F. L. Emory: The average student is vastly lacking in a knowledge of the use of logarithms. He also lacks the ability to read trigonometric formulæ from the triangle.

The tendency of the report is to include more material than can be covered in an engineering course. I would be satisfied to have a little more training in a few principles which students must know so well that they have confidence in their knowledge. One of the most serious difficulties that I encounter is with the constant of integration. This is largely the fault of the text-books. I have a grievance against the textbook writer who omits the constant in all cases, supplemented by the remark that it should always be added. We cannot expect the student to remember a footnote to be applied with each operation.

Professor J. B. Webb: I am pleased to hear what Professor Emory said about the constant of integration and his explanation of the difficulty, but I think the trouble is more in the teaching than in the text-books. In reading Mr. F. W. Taylor's book on his system, I was interested in one of the illustrations which he uses. He takes the case of loading cars with pig iron, where, by the application of his system he about tripled the amount that a man could do in a day, and at the same time enabled the man to earn more money. One of the first things he did was to examine the men that were in the gang, and he found that but one man in eight was suitable for this work. He used only those who were fitted for it. We have about the same proportion, perhaps, of the unfit in our classes, and the ones fitted for engineering could do three times the work and do it better if our classes were conducted on the Taylor system.

I have had some interesting experiences with the complex variable. Having studied the subject in Germany in 1878–1880, on my return to this country I tried to teach its use. Objections were made by those not acquainted with the subject, that it was too advanced and of little practical use, so that it proved to be harder to convince the average American teacher of its importance than to arouse the interest of intelligent students. Some of the professors were convinced, but that was where the trouble lay. If a student was conditioned because he did not get through with his mathematics, some said I taught "over his head" and gradually the standard would be forced down. The trouble with the present schools is that they want too many students and are going to hold all they have and get more if they can. They do not call out the seven and keep the one. After Dr. Steinmetz, a layman, produced his book on the treatment of alternating currents, using complex variables, there was less objection made to them. Now I say it is a disgrace that it should be necessary for a layman to show professional teachers that a certain part of mathematics is needed. What we should do is to eliminate the students who are not capable of profiting by what we know should be taught, and then hold the others to a high standard.

We expect too much of the student who takes calculus. Of a semester in calculus at least one-half is spent in reviewing previous mathematics. A course in calculus is an excellent review of geometry, algebra and especially of trigonometry, and at its close we should not expect the average student to know much more about it than he did about trigonometry at the start.

This committee was appointed to see what was the matter with the teaching of mathematics. They imply that good text-books are lacking. I cannot agree with this and would rather have one of the old-fashioned text-books than those outlined in their report. If they intend to give simply a list of subjects that students should be drilled in, well and good; but if the report intends to prescribe the methods of thought and of logical deduction, to be used in those subjects, then I think it is all wrong.

Professor Magruder: The introduction to the report states clearly the purpose of the syllabus.

Professor W. J. Risley: The suggestions that have been made here this afternoon are very good. I am in favor of a section on imaginary quantities. When I approached some of the Harvard professors of engineering subjects I found that they wanted their students to perform vector addition analytically. They said that the teachers of mathematics were teaching a lot of things of which little or no use was made later. To a great extent Professor Webb was right in stating that he had to teach the professors of engineering what they ought to teach, in order that they might understand some of the mathematics which he attempted to send to them. On the other hand, sometimes the professors of engineering have to teach the professors of mathematics some things that they don't know that their students ought to know. Neither set is to be criticized too severely unless they are unwilling to learn when the right way is pointed out.

Principal Arthur L. Williston: I was very much interested in what Professor Webb said a moment ago, referring to Mr. Taylor's work and his method of culling out one man of the eight who was especially adapted for a particular kind of work, using him intensively on that kind of work, and finding tasks for which the other seven are fitted. That idea is really at the bottom of all of our difficulty in this discussion of teaching mathematics to engineers, which we have had almost since we began trying to teach engineers. As there are few men of the naturally analytical kind that Professor Webb describes it does not make much difference what sort of methods we use with them. As a matter of fact a very small proportion of the men who form the body of eminent engineers have that type of mind. We all know the sort of fellow who thrives on complex quantities. And I am sure the majority of those here will bear me out in my statement that a very small proportion of the successful, eminent engineers of this country are of that kind. The ideal plan would be to separate those fellows from the mass and give them a course in real mathematics. They would like it and it would be a pleasure to the instructors to teach them. But let us take the other group. For the most part, the man who is going to be a successful engineer in industrial work is a practical, concrete man. He does not handle imaginary, complex, abstract quantities easily. And yet that is the very type of mind that the world wants in its important industrial activities. Those fellows, who, by the way, constitute the great majority, want mathematics not as an analytical light but simply as a necessary evil, if you please, as a tool that they must use. If in our talking and our thinking we could learn to talk of mathematics as two subjects, one thing for the first type, another for the second, it would simplify all our discussion. It is absolutely futile to attempt to teach the first kind of mathematics to three out of four young men who will be good engineers whether the colleges turn them out as fitted to be engineers or not. They are going to be engineers. As I understand it, the work of this committee has been to some extent a movement toward trying to get the teaching of mathematics for engineers differentiated from the teaching of pure mathematics. I am sorry that the difference is not more marked.

Professor E. R. Maurer: I prefer to hear a teacher of mathematics discuss this syllabus, because he can see it in the light of his experience in teaching the subject. To be sure, others have good ideas as to what knowledge and training engineers ought to have in mathematics, but they fail to appreciate the difficulties of teaching the subject. So, between two criticisms, one offered by teachers of mathematics and the other by teachers who have never taught mathematics, I place more confidence in the former. In estimating the value of mathematical instruction we are apt to forget that, in many schools, particularly the large ones, more or less inexperienced men are employed as instructors in the departments of mathematics. The results suffer on that account. In addition there is the poor quality of the working material. I try to be charitable when I judge the students that come to me from the department of mathematics on those two accounts. Many of the boys have had their training at the hands of inexperienced men and many have very little mathematical talent. I think the syllabus is good as a list of topics with which all engineering students ought to be familiar. I agree with Professor Webb in that we ought not to set this up as a subject matter for all teachers of mathematics to use and not depart from it in any particular. The teacher of mathematics, or of any subject in an engineering school ought to understand his subjects well enough to get up his own syllabus, if necessary.

The President: An informal committee of instructors in the University of Illinois, formed of a dozen men representing the department of mathematics, mechanics, civil engineering, electrical engineering and mechanical engineering, made a careful study of the report of the Mathematics Committee to see whether the syllabi covered the ground which these professors thought should be covered in class. In general I may say that they approve almost wholly of the contents and in general of the matters of emphasis as to what part should be well understood, what other, only partly known. With your permission I shall include this report in the discussion.

The committee of University of Illinois instructors selected to discuss the preliminary report of the Committee on the Teaching of Mathematics to Students of Engineering submit the following recommendations:

Since the syllabi are meant to embody the minimum equipment in mathematics of a good engineer, they have been discussed from that point of view. But it is the opinion of the committee that much could be gained by publishing a list of topics that should be included in the courses discussed, and emphasizing by a star those which are "so essential that every engineering student should have them so firmly fixed in his memory that he will never need to look them up in a book." The discussions of the committee were confined to the syllabi which are printed in the *Proceedings, i. e.,* Algebra, Trigonometry, Analytic Geometry, and Calculus. Section numbers refer to the sections as published in the syllabus.

Algebra.

1. Under factoring some mention should be made of the important cases of collecting coefficients, and of quadratic trinomials.

2. Important principles and rules should be given in translated word form as well as in symbolic form (as is done once on page 172 and in the differentiation rules in the calculus syllabus). Students often fail to get the full meaning of symbolic forms. The operations with fractions and the definitions and laws of exponents especially need statement in word form.

3. If algebra follows trigonometry, the three forms for imaginaries should be included.

4. The notions equality, identity and equation should be carefully differentiated.

5. The principles of equivalent equations should be included, for a student should know what operations introduce or take out roots.

6. More emphasis is needed on the "completing the square" process, for it is often needed later in integration and analytics when no solution is required.

7. Harmonic progression should be omitted.

Trigonometry.

1. The committee agrees that the syllabus is satisfactory and probably is complete enough for the average engineer. Some members expressed a desire for the memorization of more formulas as particularly useful to electric engineers.

2. Some members desired greater stress on the visible handling of formulæ. By visible is meant graphical so far as the expression of relationship and formulæ can be. For example the student should not so much remember the six fundamental definitions as formulæ as he should remember the defining triangle and its ratios. The same idea should be carried throughout.

Analytic Geometry.

1. The syllabus states in the introduction, "This syllabus is confined mainly to the conic sections; but a satisfactory course in analytic geometry should include also the study of many other curves." This committee believes that the syllabus would be improved by including the most important of these "many other curves" including the so-called engineering curves.

2. The equation of a straight line passing through two given points should be included.

3. The equation of a straight line should be written in such a form and taught in such a manner that *all* constants of the line are readily determined.

4. The method of treating the conic sections in the syllabus is commended. For obtaining a proper facility in handling the practical applications of these curves, it is desirable to study each form separately even at the expense of the additional time that is required when this method is employed. The properties of these curves as given are amply sufficient.

5. The geometrical construction of the conics should be included and given more than a mere reference.

6. In the transformation of coordinates the method rather than the equations should be remembered.

7. The subject matter in articles 46–54 is not that which a

student should remember, but belongs to that class of things which can easily be referred to when required.

8. Much greater emphasis should be placed upon work in polar coordinates.

9. It is desirable for the student to be familiar with cylindrical coordinates and the committee commends the inclusion of these coordinates in the syllabus.

10. Great stress should be laid upon representation with space coordinates. Any single equation in space coordinates represents some surface. If the equation is in three variables the surface may be any form, if in two variables the surface is a cylinder, if in one variable the surface is a plane or a system of planes parallel to one of the coordinate planes. Great emphasis should be placed upon the fact that it requires a pair of simultaneous equations to determine a line in space.

11. Article 71 should be omitted from the syllabus, though included in a course in Analytic Geometry.

12. In the first sentence of the second paragraph of the introduction the phrase "a course should consist *chiefly* of problems" should be changed to read "a large number of problems should supplement the treatment of general principles."

Calculus.

The committee reports very favorably on the syllabus for the first part of calculus. A subcommittee drew up a synopsis of a course in calculus before reading the syllabus as printed in the *Bulletin*. The two did not differ in many essential details. The main question that came up was whether a topic was included under "those facts and methods which every student should have so firmly fixed in his memory that he will never need to look them up in a book," or simply under "those topics included in an elementary course in calculus." These two classes are referred to below as first and second classes. The specific changes suggested in the syllabus are as follows:

1. Section 5. Hyperbolic functions should be included in the second of the above classes. Mnemonic rules for changing

a trigonometric formula to the corresponding formula in hyperbolic functions should be included.

2. Use arcs in x, arc cos x, etc., instead of $\sin^{-1} x$, $\cos^{-1} x$, etc.

3. Section 21 (Formal work in integration). Tables of integrals should not be used until the student has had considerable practice in formal integration.

4. Include in section 22, integration by separation into partial fractions.

5. Much practice in differentiation and integration with respect to variables represented by symbols other than x, y, z should be given.

6. In connection with differential equations (Sections 24, 25, 26) use d^2y/dx^2 instead of dy'/dx.

7. Include linear differential equations of first order in connection with sections 25, 26.

8. Include sections 15 (Theorems on infinitesimals), 22 (Integration formulas), 35 (Theorem of Duhamel), 38 (Subtangents, subnormals, etc.), 41 (Curvature), in the second of the above classes.

9. Include angular velocity and acceleration in section 42.

10. We particularly commend sections 7, 12 (note) and 14.

Professor A. M. Buck: A good many people, and especially some who are mathematicians, forget that with the engineering student mathematics is a subject that is taken not for its own sake, but in order that problems can be solved afterwards. If we take the view-point of the students we find that they appreciate this point better than their teachers do. Students have told me that they could not get along in mathematics because they did not know what use they were going to make of it. Had it been brought to their attention that the mathematics would have some application to their engineering work they would have gone into it with good spirit and would have obtained more benefit from the work. Taking it as an abstract study they simply would not give it the necessary time. If the teacher of mathematics will look at his subject from an engineering view-point and see that those things which he teaches are to be used as tools and that the better the student has his tools in hand the better work he can do, then there will be an improvement in the teaching.

Professor H. R. Thayer: I am going to state my opinion from the view-point of the engineer. I have spent more time outside in practice than I have in teaching. All of the latter has been along the line of structural design, where I have been using the work of the mathematical department. In the first place, in my experience as a student, mathematics came fairly easy to me. I found that when an examination was imminent, I could cram up for it the night before and forget it afterwards. That is about what nineteen out of twenty students will do. Complicated notation tends to discourage the student from getting what is extremely important to get, namely, fundamental principles. I find that students know their mathematics fairly well but they don't know how to apply it. This, it seems to me, is far more important for them to learn than such extremely complicated mathematical problems as are often given them. In actual engineering experience the applications of any but these fundamental formulæ are few and far apart. In the very infrequent cases where the more complicated formulæ are used it is only necessary to refer to tables in the text-books, as the majority of successful engineers do today. In my opinion, the ideal engineer need not have an extremely mathematical training. In running a railroad, it is far less important to get the line exactly curved and mathematically accurate, than it is to run it where it will cut least into expenses, which is the main point involved. Imaginary quantities do not teach this. The student must be taught to use efficiency engineering in handling his mathematics. If this can be taught well, we shall have better engineering students than if we attempt to teach them to handle their problems by imaginary complex quantities.

Professor G. H. Morse: A previous speaker has referred to alternating currents and to lack of familiarity with the mathematics needed for this subject. I wish to emphasize the absolute necessity for a certain amount of study of complex quantities in this connection. I recently made a tour of a number of western institutions—Illinois, Purdue, Armour Institute, and Wisconsin—with the object of discovering how the professors were teaching electrical engineering. At Illinois I found Professor Berg, who spent a great many years at the General Electric works developing their many products. I learned that he has given up entirely all methods of teaching alternating currents except that involving the use of complex quantities illustrated by graphics, of course. He insists upon this method, both for himself and his assistants. The so-called trigonometrical methods have no standing with him whatever. At Purdue I found Professor Harding, and his attitude, while not as radical as that of Professor Berg, was very similar. In my own case I find that the use of complex quantities in teaching alternating currents is wonderfully elucidating in certain parts of the subject.

Some years ago I had the notion that there was mathematics for engineers to use, the kind that is a necessary evil, and that there was mathematics for mathematicians, in which they had great pleasure in soaring, and which they jealously guarded from use, preferring not to have any practical applications made of it. Since I have been associated with the mathematicians at the University of Nebraska my ideas have entirely changed. I now find that every stage of these flights in pure mathematics is a "short cut." The higher the flight the shorter and more useful the cut. If only the engineers can appreciate these flights their work will be greatly simplified.

Professor S. B. Charters, Jr.: I wish to emphasize the fact that we are dealing in engineering with two totally different classes of students. In every group, in the proportion of about one to fifteen or twenty, there is one engineer. Such a man should have and will take and enjoy the fullest mathematical training. On the other hand, the comparatively larger number are not engineers at all. They are simply men who are getting a certain amount of engineering training; and these men fill the bulk of the positions. From the colleges of the west a great many must go out into practical work as mining superintendents, superintendents of construction in the installation of plants, etc. Now that class of work absorbs the bulk of our men, and these have no use for higher mathematics whatever. It might be a help to them and it might not. Among those graduates whom I have observed, the ones who have had the best success have not been great mathematicians. The highest paid man we have among our alumni today, is one who could not pass any mathematical examination, I am reasonably certain. We have a few men who graduate every year who should be given higher mathematics. We have a feeling that, if it were possible, engineering should be divided into two courses; the longer course of, say, five or six years, with adequate mathematical training, for the man who shows special aptitude on those lines. Those men should be the leaders in the designing branch of the profession. A second class of men need not have the higher mathematics, but should have the proper training in handling men. These must do the bulk of the work. We need a certain number of men to do the designing and hand down formulæ which these other men can follow. We need more men to take those mathematical formulæ and from them get the results. That was illustrated to me by a friend who stated that in the American Bell Telephone Company there is one man who does the principal mathematical work for the system. In each division they have mathematicians to interpret this work to the rank and file. Probably twenty-five or thirty experts do the mathematical work for this large company and the rest of it is done by the engineers who need have only the ordinary mathematical training.

Professor H. S. Jacoby: Allow me to call attention to the fact that this report deals with minimum requirements, and that we should express our appreciation of the splendid work done by the committee. The report may not be perfect in every part, but it will be worth a great deal to have it adopted, printed and made available to the teachers whose work is affected by it. It may be made a starting point for definite recommendations; changes may be made later as the necessity for them appears. If in any institution the mathematical courses are of such a character as to require enlargements to conform to the recommendations, it is very likely that they will be modified in time. The report ought not to be a hindrance to any teacher of mathematics, or to any course of study which is now more extensive in its scope.

Professor Webb: It occurs to me that there is something else that can be said about the cause of the trouble between engineers and mathematicians. An engineer very often has a problem that he does not see through. He has a general idea that mathematics is a powerful instrument, which needs a mathematician to solve the problem; and he thinks that if he knew a little more mathematics he could solve it himself. As a matter of fact, the problem may be very simple as to its mathematics, and it may be only that he does not see through its practical or engineering side. A school teacher came to me with a problem a few days ago and said she had given it to different people to solve, and some advocated one solution and some another. One said that its solution needed calculus; I thought it could be solved quite simply, but she thought not. This was a problem of the so-called practical variety. A barn forty feet square has a horse tethered to one corner of it by a rope one hundred feet long. How much grass can the horse graze over without going over the same grass twice? The solution of this is very simple, but one should not expect mathematics to solve it before the problem has been thoroughly analyzed. Problems of this nature are constantly met with in engineering work. Very little mathematics may be needed after they are properly analyzed, but if this calls for more common engineering sense and ingenuity than the engineer has, one must not expect the average mathematician, much less the recruit graduate, to make good the deficiency.

SYLLABUS ON COMPLEX QUANTITIES.*

BY CHAS. O. GUNTHER,

Professor of Mathematics, Stevens Institute of Technology.

1. Derivation of formulæ:

$$e^{i\theta}=\cos\theta+i\sin\theta,\qquad e^{-i\theta}=\cos\theta-i\sin\theta,$$
$$\cos\theta=\frac{e^{i\theta}+e^{-i\theta}}{2},\qquad i\sin\theta=\frac{e^{i\theta}-e^{-i\theta}}{2}.$$

2. Definition and graphical representation of a complex quantity. Polar trigonometric and polar exponential equivalents of $z=x+iy$, that is,

$$z=\rho(\cos\theta+i\sin\theta),\quad \text{polar trigonometric;}$$
$$z=\rho e^{i\theta},\quad \text{polar exponential;}$$

in which $\rho=\sqrt{x^2+y^2}$ is the *modulus* (the positive sign being always associated with it); and θ, given by the relation $\tan\theta=y/x$, is the *argument* of z. Any multiple of 2π may be added to the argument without altering the complex quantity.

3. Graphical addition, subtraction, multiplication and division of complex quantities. Graphical solution of the equation $x^n\pm1=0$. Logarithms of complex quantities.

APPLICATIONS TO INTEGRATION.

4. The expression

$$dy=\tan^{2p}\theta\sec^{2r+1}\theta d\theta,$$

in which p and r are positive integers or zero, is by the substitution $\tan\theta = i\sin\alpha$ (α being an imaginary quantity) transformed into

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* This syllabus was prepared as an appendix to the report of the Committee on the Teaching of Mathematics to Engineering Students at the request of the members of the Society present at the Pittsburgh meeting.

$$dy = i(-1)^p \sin^{2p}\alpha \cos^{2r}\alpha d\alpha.$$

This latter expression can be integrated by doubling α as many times as necessary.

The foregoing includes the integration of the expression

$$dy = \cot^{2p}\theta \csc^{2r+1}\theta d\theta,$$

since the latter expression may be written

$$dy = -\tan^{2p}\left(\frac{\pi}{2} - \theta\right)\sec^{2r+1}\left(\frac{\pi}{2} - \theta\right) d\left(\frac{\pi}{2} - \theta\right).$$

As found in text-books, the integration of the expression

$$dy = \cos^h\theta \sin^k\theta d\theta \tag{1}$$

is readily accomplished in three cases, namely:

(*a*) When either h or k is an odd positive integer.

(*b*) When $h + k$ is an even negative integer.

(*c*) When both h and k are even positive integers, or zero.

The first two of these cases include *fractional* values for h and k.

By means of the substitution given above, all the other cases in which h and k are integers can be brought under one or more of the three cases just mentioned.

In the above are also included all the cases for which the general binomial differential expression

$$dy = x^m(a + bx^n)^{p/q}dx$$

can be integrated without resorting to infinite series. This expression is only another form of (1), since $\sqrt{a + bx^n}$ can always be represented by one of the three sides of a right triangle and therefore expressed as a trigonometric function of one of the acute angles of the triangle.

In determining the value of a definite integral, if the variable is changed the limits should be changed to correspond. For example, in finding the length of the arc of the parabola,

$y^2 = 4ax$, from the vertex to the point $(a, 2a)$, we have

$$S = \frac{1}{2a}\int_0^{2a} \sqrt{4a^2 + y^2}\, dy$$

$$= 2a \int_{\tan\theta=0}^{\tan\theta=1} \sec^3\theta\, d\theta$$

$$= 2ai \int_{i\sin\alpha=0}^{i\sin\alpha=1} \cos^2\alpha\, d\alpha = ai \int_{i\sin\alpha=0}^{i\sin\alpha=1} (1 + \cos 2a) d\alpha$$

$$= a \log_e(\cos\alpha + i\sin\alpha) + ai\sin\alpha\cos\alpha + C \Big]_{i\sin\alpha=0}^{i\sin\alpha=1}$$

$$= a\left[\log_e(\sqrt{2} + 1) + \sqrt{2}\right].$$

Further applications of complex quantities to integration will be found in the author's discussion on p. 283.

THE TEACHING OF ELEMENTARY DYNAMICS.

BY WILLIAM KENT,
Montclair, N. J.

In the preceding pages is given the revised report of the Committee on the Teaching of Mathematics to Engineering Students, which committee was appointed at a joint meeting of the American Mathematical Society and Sections A and D of the American Association for the Advancement of Science in December, 1907.

The preliminary report of the committee was presented in the form of galley proofs at the meeting of the Society for the Promotion of Engineering Education at Madison, Wis., in June, 1910. This preliminary report contained a chapter on ''Elementary Dynamics,'' a criticism of which by the present writer was printed in *Science,* May 5, 1911. At the Pittsburgh meeting, in June, 1911, it was announced that the chapter had been withdrawn from the report, as the committee had not been able to agree upon the method of presenting the subject. This action of the committee is in harmony with that of a conference of teachers of physics in 1909, a majority of whom signed a statement, ''that colleges should require of schools no quantitative treatment of kinetics, or the behavior of matter undergoing acceleration.'' (See *Science,* October 29 and December 24, 1909.)

The reasons why many teachers find it so difficult to teach dynamics and why conferences of teachers and committees fail to come to an agreement as to the methods of teaching it, have been given at some length by the writer in three articles in *Science* of December 24, 1909, May 27, 1910, and May 5, 1911, and it is not necessary to repeat them here. Let us acknowledge the lack of agreement and see if some basis can be found upon which an agreement may ultimately be founded. There is no difference of opinion as to the fundamental facts of dynamics. Everyone knows that matter is stuff that occupies space and is attracted by the earth's gravitation, and that its quantity can be ascertained by weighing it. Everyone knows that force is either a push or a pull, and that the amount of a force can be ascertained by means of a spring balance. Everyone knows what is meant by the words time and space. Every teacher of physics or mechanics can easily calculate the results which follow the action, for a given time, of a constant force upon a given quantity of matter which is free to move, and he has definite concepts of velocity, acceleration, momentum, energy, etc. It is only when the teacher attempts to convey his knowledge to the student that he meets with trouble.

In the writer's opinion the difficulty is not due to the facts but only to the language in which the facts are presented. The writers of text books have made the subject obscure by using new forms of words to express their ideas, by inventing new terms, such as the ''poundal'' and ''gee-pound,'' and by lack of clearness and precision of statement. What is wanted is to put the subject of elementary dynamics into language which can be understood by every high school student, so brief that it can be memorized, scientifically correct, and unencumbered by unnecessary ideas or words.

The following is an attempt to meet this requirement. The writer asks for it the careful attention of teachers of engineering students, and if anyone is disposed to object to it either in gross or in detail, will he kindly write out his own method of presenting the subject for the purpose of comparing it with the writer's method. Constructive criticism is wanted, with the end in view of ultimately finding a form of words which text-book writers will adopt as the form which will most easily give the student the ideas he should have concerning elementary dynamics.

ELEMENTARY DYNAMICS, ENGLISH SYSTEM.

We deal with four things or elementary quantities:

Matter,	W pounds
Force,	F pounds
Time,	T seconds
Space,	S feet

and two derived quantities, velocity, V feet per second, and acceleration, A, the rate of change of velocity, feet per second per second.

Fundamental Statement.—A force F acts during a time T, on matter W, at rest at the beginning of the time, but free to move, and causes it to move during the time T, through a distance S. It is required to find the relations or algebraic equations between the several quantities W, F, T, S, V, A. Thus if a given force F acts on a given quantity of matter W at rest but free to move, what is the velocity V, acquired at the end of that time, what is the acceleration, and what distance does the body move?

I. *Special Case: Falling Bodies.*—F and W are constant and numerically equal; $F = W$. It is found by experiment that a body falling freely (at lat. 45 degrees and the sea level) from a state of rest for one second, acquires by the end of the time a velocity of 32.174 ft. per second. This figure is represented by g.

It is also found that at the end of times

	$T =$	1	2	3	4	5 seconds.
The velocity	$V =$	g	$2g$	$3g$	$4g$	$5g$ feet per sec.
The space traversed each sec.	$S =$	$\frac{1}{2}g$	$\frac{3}{2}g$	$\frac{5}{2}g$	$\frac{7}{2}g$	$\frac{9}{2}g$ feet.
Total space traversed	$=$	$\frac{1}{2}g$	$\frac{4}{2}g$	$\frac{9}{2}g$	$\frac{16}{2}g$	$\frac{25}{2}g$ feet.

If $V_1 =$ the velocity at the beginning of any period of time t and V_2 the velocity at the end of that period, the acceleration

$$A = \frac{V_2 - V_1}{t} = g, \text{ a constant.}$$

Thus let $t =$ the two seconds elapsing between the end of the third and the end of the fifth seconds,

$$\frac{V_2 - V_1}{t} = \frac{5g - 3g}{2} = g.$$

Also $A = V/T = g$, V being the velocity at the end of any time T.

From these experimental facts we derive the equations

$$V = gT; \quad S = \tfrac{1}{2}gT^2 = \tfrac{1}{2}VT; \quad V = \frac{2S}{T}; \quad V^2 = 2gS;$$

$$V = \sqrt{2gS}; \quad S = \frac{V^2}{2g}; \quad A = g.$$

W and F do not appear in these equations, but since in the case considered $W = F$, we may multiply (or divide) one side of either of the above equations by W and the other side by F, and they will remain true, thus we obtain

$$FT = \frac{W}{g} V; \quad AW = Fg,$$

whence $F/A = W/g$.

If we substitute the letter M for W/g we have

$$FT = MV; \quad F = MA.$$

II. *General Case.*—F equal to, or greater or less than W,

let $a =$ the acceleration $= >$ or $< g$.

It is found by experiment that if W is constant and it is acted on by different forces F_1, F_2, F_3 (at different times), the accelerations produced, a_1, a_2, a_3, are directly proportional to the forces.

Also if the force is constant, and it acts on different quantities of matter, W_1, W_2, W_3, the accelerations a', a'', a''', are inversely proportional to the W's.

These two facts are expressed by the formula $a \propto F/W$ which is read: a varies directly as F and inversely as W.

From algebra we know that the expression $a \propto F/W$ is equivalent to $a = cF/W$, or $aW = cF$, in which c is a constant for all values of F and W.

From falling bodies we have $AW = gF$, therefore the value of c is g, and $aW = gF$ is a general equation for any value of F and the corresponding acceleration produced by F; and since $a = V/T$ we have $FT = MV$, $F = MA$, as in the case of falling bodies.

These equations are therefore general and apply to all cases of the action of a constant force on a body free to move.

The expression $FT = MV$ is sometimes translated "Impulse = momentum," but impulse is merely the product FT and momentum the product MV.

Energy, the capacity for performing work. Work is the product FS (in foot-pounds) of a force into the distance through which it is exerted. If we lift a body of W pounds by applying a force $F = W$, overcoming gravity, through a height S, the work done is $FS = WS$. When held at that height the body is said to have potential energy WS. If it now falls through the height S, it acquires a velocity $V = \sqrt{2gS}$ and the body now has kinetic energy, numerically equal to the work done in lifting it, $FS = WS$. Substituting for the last S its value $V^2/2g$ we have $FS = WV^2/2g = \frac{1}{2}MV^2$, the equation of work done and kinetic energy.

METRIC SYSTEM.

In the metric system of weights and measures all the formulæ given above apply just as they do in the English system, but the word "kilograms" is substituted for "pounds" and "meters" for "feet," and the value of g is 9.807 meters or 980.7 centimeters.

C.G.S. SYSTEM.

In the C.G.S. (centimeter-gramme-second) system, space S is measured in centimeters, quantity of matter M, in grammes, time T, in seconds, and force F, in dynes, a dyne being defined as that force which acting for 1 second will give to 1 gramme of matter a velocity of 1 centimeter per second, or it is $1/980.7$ of the force which gravity exerts on a gramme of matter at lat. 45° at the sea level. The value of g is 980.7 centimeters.

DEFINITIONS.

One pound of matter is the quantity of matter contained in the standard pound, a piece of metal preserved in London. One pound force is the force which gravity exerts on a pound of matter at lat. 45° at the sea level, or that force which will give to matter free to move an acceleration of 32.174 feet per second per second.

Weight.—The word "weight" is used in two senses, just as the word "pound" is, to express both quantity of matter and the force which gravity exerts on matter. If the pound force is rigidly defined as above and if the quantity of matter is determined by weighing it on an even balance or platform scale (not a spring balance) no confusion need result, for the pounds weight (quantity) and the pounds force are numerically equal to each other.

If, however, the weighing is done on a spring balance (since the force of gravity varies at different latitudes and different elevations above sea level) the apparent or "local" weight may differ as much as 1 part in 1,000 from the true weight (quantity) as determined by weighing on an even balance.

Mass.—In the C.G.S. system the word "mass" is used for quantity of matter M. In the English system the word "mass" and the letter M are used to express the quotient W/g or the quantity of matter in pounds divided by 32.174.

On account of the ambiguity and double use of the words weight and mass, both of these words have been omitted in the above elementary discussion of the subject. The word "unit" has also been omitted.

The following equations should be memorized and clearly understood by the student: $M=W/g$; $FT=MV$; $F=MA$; $FS=\frac{1}{2}MV^2$; $V=\sqrt{2gH}$. ($H=$ the height a body falls to acquire the velocity V.)

BALANCE OF COURSES IN CHEMICAL ENGINEERING.

BY CHARLES H. BENJAMIN,

Dean of the Schools of Engineering, Purdue University.

Introduction.

Chemical Engineering as a distinct profession is growing and its development, although steady, is slow. The pressure for the introduction of separate courses in this branch of engineering has come from without rather than from within. Professors, whether of chemistry or of engineering, have been inclined to look askance on this newcomer as the offspring of an unholy alliance, but the growing demand for men who possess a working knowledge of both professions is gradually reconciling them to the new arrangement.

In studying the development of chemical engineering, we have but to hark back twenty years and read the description in college catalogs of the courses in electrical engineering as they then existed.

The increasing use of electricity in the production of light, heat and power and in telephone service brought with it a demand for men who combined engineering training with a knowledge of the new agent. This demand received at first a half-hearted consideration from the faculties of our engineering schools. Perhaps the professor of physics took charge of the new department, bought a dynamo or two and grafted a little engineering on the science course. More frequently the professor of mechanical engineering assumed a double title and brushed up his knowledge of volts and amperes.

Gradually the warring elements were brought into harmonious relations, the useful was retained, the useless dropped, and under the administration of an electrical engineer, the course attained the place and the dignity which it deserved.

In a somewhat similar way, new enterprises and new combinations are seeking for men who have both chemistry and engineering, and these men will be called in the future "chemical engineers."

The professor of chemistry and the professor of mechanical engineering are just now a trifle at sea as to the parentage of this last addition to the college family, but we have a right to infer from past history that their differences will be adjusted, that the right balance will be established and that under the leadership of a chemical engineer, the new course will take its rightful place among its brethren.

Definition.

The chemical engineer may perhaps be described as a man who is competent to so superintend a manufacturing plant as to insure both the chemical purity of the product and economy in the mechanical operation of the factory. As a natural result of conservation and concentration, establishments are now built and equipped for the manufacture on a large scale of various products used in the arts, which were formerly made in smaller quantities at a much greater unit cost. Paints and oils, varnishes, acids, petroleum products, soap, sugar, starch, glass, pottery, explosives, paper, cement, bleaching powders, nitrates,—are examples of products requiring for their economical manufacture, knowledge of both mechanical and chemical processes.

Some companies have attempted to solve the problem by employing two men, an engineer and a chemist, and trusting to their joint efforts. At its best, dual control is unsatisfactory and inefficient, leading to divergence and misunderstanding. The one man should rule and he should be capable of meeting all problems that arise, whether chemical or mechanical.

How Taught.

There have been and still are marked differences of opinion among educators as to the methods of teaching chemical engineers and as to the relative amounts of engineering and chemistry to be put in the curriculum. Naturally, when the department has been an outgrowth or development of the course in chemistry, that science has received the more attention. In other colleges, the addition of more chemistry to the course in mechanical engineering has left the greater weight on the engineering side.

TABLE I.

Chemical Engineering. Actual Hours per Week.

	Michigan.		Massachusetts.		Purdue.		Wisconsin.	
	Rec.	Lab.	Rec.	Lab.	Rec.	Lab.	Rec.	Lab.
English	4		8		9		6	
Language	16		8		16		8	
Economics			8		6			
Letters	20		24		31		14	
Mathematics	18		14		22		19	
Physics	8	6	11	6	9	4	8	8
General science						4		
Science	26	6	25	6	31	8	27	8
Drawing		12		32		24		18
Shop		12		2		12		10
Mechanics	4		8		8	2	13	
Mechanical engineering	4	6	9	2	8	3	8	19
Electrical engineering	2	6	2	3	6	6	4	8
Civil engineering	2	6						
Engineering	12	42	19	39	22	47	25	55
General chemistry	4		7	8	4	6	4	8
Qualitative analysis	4	12		8	4	12	2	8
Quantitative analysis	4	18		21	4	12	2	8
Organic chemistry	5		7	11	4	12	4	12
Industrial chemistry	12	21	6	12	8	24	11	18
Inorganic chemistry			2					
Theoretical chemistry			6	6				
Chemistry	29	51	28	66	24	66	23	54
Electives theses	5	12					4	24
Totals	92	111	96	111	108	121	93	141

The accompanying tables and diagrams show the distribution of work by hours in the chemical engineering courses of eight representative institutions. These figures were originally compiled from catalogues and in all cases but one were referred to the professors in the various colleges for correc-

TABLE II.

Chemical Engineering. Actual Hours per Week.

	Illinois.		Pennsylvania State.		University of Pennsylvania.		Columbia.	
	Rec.	Lab.	Rec.	Lab.	Rec.	Lab.	Rec.	Lab.
English	6	......	13	......	9			
Language	8	......	15	......	12			
Economics	6	......	14	......	3			
Letters	20	......	42	......	24			
Mathematics	15	......	20	......	18	......	15	......
Physics	4	10	7	4	7	4	12	......
General science	4	6	......	......	2	......	......	6
Science	23	16	27	4	27	4	27	6
Drawing	......	......	2	17	......	12	4	20
Shop	......	......	......	7	......	12	......	7
Mechanics	8	3	7	4	17	......	12	6
Mechanical engineering	3	6	12	......	19	6	19	12
Electrical engineering	......	......	6	15	9	12	4	3
Civil engineering	......	......	......	......	......	......	2	10
Engineering	11	9	27	43	45	42	41	58
General chemistry	5	8	6.5	5	6	12	6	......
Qualitative analysis	1	7	......	7.5	10	18	4	13
Quantitative analysis	4	20	2	16.5	12	18	8	24
Organic chemistry	6	12	2	......	8	20	10	18
Industrial chemistry	14	30	11	36	7	17	38	22
Inorganic chemistry	......	......	......	......	......	......		
Theoretical chemistry	......	......	......	......	2	6		
Chemistry	30	77	21.5	65	45	91	66	77
Elective theses	2	4						
Totals	86	106	117.5	112	141	137	134	141

tion. They probably represent closely enough for our purpose the relative times assigned to the different branches.

For convenience of comparison, the subjects have been arranged in four groups: (1) Letters, comprising all language work, economics and history; (2) science, embracing mathematics, physics and geology; (3) engineering, covering all technical subjects not chemical in character; (4) chemistry, embracing all chemical subjects whether theoretical or technical.

The exact arrangement and definition of subjects in the chemical group is probably not always correct but as the comparison is to be made by groups, this is not important.

The tables show the actual or clock-hours per week for the entire course added together.

Diagram 1 represents the times of the various groups graphically, the upper line in each case being class room work and the lower line laboratory, shop or drafting room time.

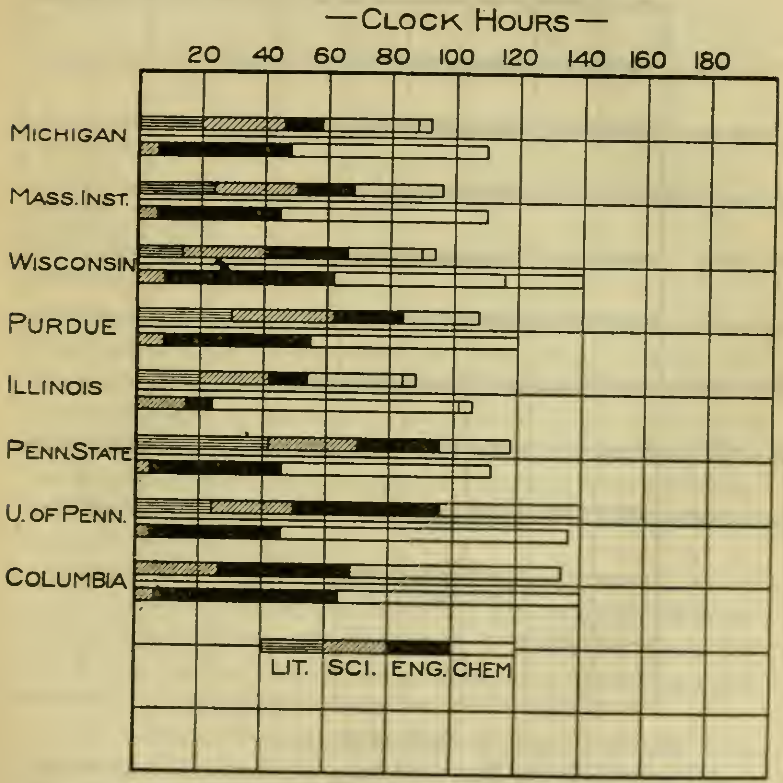

DIAGRAM 1.

In Diagram 2, the two sets of hours have been added by reducing to credit hours. Each class room hour is rated as one credit hour and two and one-half laboratory hours are allowed the same weight. This is the ratio obtaining at Purdue University and is about an average of those in common use.

Whenever the hours of chemistry are divided in two parts, the right hand portion represents elective work and is not necessarily chemistry.

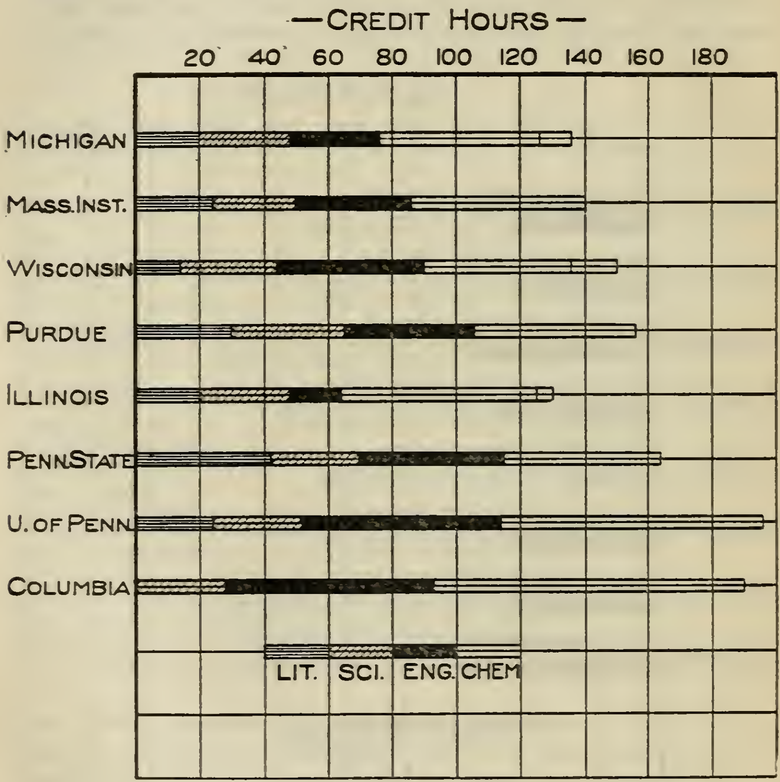

DIAGRAM 2.

In Diagram 2, the first four lines represent the courses at present in the Massachusetts Institute of Technology and in the universities of Michigan, Wisconsin and Purdue. These are somewhat similar in the balance of subjects and perhaps represent a happy mean. The percentages of total time are as follows:

TABLE III.

	Letters.	Science.	Engineering.	Chemistry.
Michigan	14.7	20.6	21.3	43.4
Massachusetts Institute	17.1	19.3	25.0	38.6
Wisconsin	9.4	20.0	31.3	39.3
Purdue	19.9	21.8	26.2	32.1
Average	15.3	20.4	25.9	38.4
Or, in round numbers,	15	20	25	40 %

The courses represented by the last four lines in Diagram 2 can not be so easily averaged. Not only do the totals differ considerably but the percentages of subjects vary widely.

TABLE IV.

	Letters.	Science.	Engineering.	Chemistry.
Illinois	15.5	22.5	11.6	50.4
Pennsylvania State	25.8	17.8	27.0	29.4
University of Pennsylvania	12.3	14.8	31.8	41.0
Columbia	....	15.3	33.6	51.1

Examining the tables and diagrams somewhat in detail, we find that Michigan differs from the other three in Table III. by having less engineering, and reference to Table I. shows this deficiency to be due to a relatively light class room schedule in mechanics and mechanical engineering. Wisconsin is noticeable for the small amount of time in letters. A few hours taken from engineering and added to letters would restore the balance.

Illinois has relatively less engineering and more chemistry than the other institutions, while the total number of hours is less than the average. Reference to Table II. shows this to be due to the almost entire absence of mechanical and electrical engineering.

The course at Pennsylvania State College is marked by a relatively large amount of letters and a small amount of chemistry, in other words, the course is broader and less technical than the others.

The two last institutions on the list, Pennsylvania and Columbia, have apparently much heavier schedules than is usual, averaging thirty-three per cent. greater than the 145 hours which represents the mean weight of the courses in Table I.

Comparisons of total weight are, however, somewhat uncertain, owing to the different ratios used in determining credit hours at the various institutions.

A peculiarity of the course at Columbia is the omission of all work in language or economics, the schedule being entirely of a technical character. The wisdom of this is doubtful. It is but fair to say that a collegiate preparation is recommended and that the regular requirements for admission to the school include considerable language and history.

In institutions for the Middle West, it is necessary for a well-balanced education that literary training should form a considerable part of the technical courses.

Cornell, Worcester and Minnesota have not been included in the list. At Cornell there is no course in chemical engineering as such. A special course in chemistry allows the student to take a small amount of engineering work, amounting to about 20 credit hours for the entire course. Similarly, students in mechanical engineering may take certain electives in chemistry covering 10 or 12 credit hours.

At Worcester, a fifth year, leading to the degree of chemical engineer is added to the regular course in chemistry and is made up almost entirely of mechanical and electrical engineering subjects.

At Minnesota there is a five-year course in applied chemistry.

The work at the three institutions last named can not consistently be compared with the four-year courses shown in the tables.

ADMINISTRATION.

The location and administration of courses in chemical engineering vary so widely that no general statement can be formulated as may be seen by reference to Table V.

The tendency seems to be to regard this course as belonging with the engineering courses in the school or college of engi-

TABLE V.

Institution.	Course in Chemical Engineering.	
	School or College.	Administrator.
Michigan	Engineering.	Professor of chemical engineering.
Massachusetts Institute	Chemistry.	Professor of chemistry.
Wisconsin	Engineering.	Professor of applied electro-chemistry.
Purdue	Engineering.	Professor of chemistry.
Illinois	Science.	Professor of chemistry.
Pennsylvania State	Natural science.	Professor of chemistry.
University of Pennsylvania	Engineering.	Professor of chemistry.
Columbia	Mines, engineering and chemistry.	Professor of industrial chemistry.

neering. On the other hand, it is usually administered by a chemist. At Michigan, Wisconsin and Columbia he is to all intents and purposes a chemical engineer, if we may judge by his title.

CONCLUSIONS.

The chemical engineer occupies a different field from that of the analytical chemist and requires a different training. The analytical chemist, as employed for instance, in the manufacture of iron and steel, is usually a subordinate; he examines the product and determines its good or bad characteristics but has little or nothing to do with the management of the business or the superintendence of the processes of manufacture.

On the other hand, the chemical engineer in a cement or an acid factory may well be the superintendent or works manager and must be competent to direct the mechanical as well as the chemical processes of manufacture, to buy and maintain machinery and to hire and discharge men. He must then have a fair engineering training in addition to a working knowledge of technical or industrial chemistry. His course in college must not be narrow but broad and general and it is better that the course be administered by a chemical engineer, one who is entirely competent himself to fill the positions for which he is trying to fit the student.

No attempt has been made in this paper to discuss the technical details of the work either in chemistry or engineering. Perhaps some difference of opinion may exist as to the proper place of subjects such as electro-chemistry, but in this analysis everything has been credited to chemistry which involves chemical knowledge and manipulation.

As most of the material herein used has been taken from current catalogs, some mistakes may have occurred, but it is believed that the relative proportions have been preserved. It is hoped that attention may be called to any mis-statements or inaccuracies as the sole purpose of the paper is to bring out facts as a basis for discussion.

Discussion.

Dean F. L. Bishop: A description of the work in this line which we are undertaking at the University of Pittsburgh may be of interest. The students in Chemistry have a course in engineering administered in connection with our cooperative system by which the student will have a year of practical work in some of the industries of this district. During the senior year he will do his research work, or at least he will assist some of the Fellows in Industrial Research in work along some particular industrial line. For instance, we have industrial fellowships in glass manufacture and the student may take up work in this line in the research laboratory and do cooperative work in some of the larger glass plants. The object, at the present time, of our course in chemical engineering is to develop a man who can take up some particular subject and carry it on with success after he leaves us.

Professor Hugh Miller: Mention is made in the paper of the encroachment of the chemical engineer upon the domain of the mechanical engineer, but no mention is made of the fact that he is also encroaching upon the domain of the civil engineer. I refer to the work in sanitary engineering more particularly, where, in sewage disposal and in the filtration of water, the chemical engineers are planning to supplant the civil engineers. A great deal of work has been thus taken away from the civil engineer in times past, and this will undoubtedly continue as long as the present tendency toward specialization exists.

Professor Morse: The civil engineer has spoken and the mechanical engineer has been spoken for, and with reference to electrical engineering there is a vast field that is at present common to the chemical engineer and electrical engineer, the field of electricity and chemistry combined. At the University of Nebraska electrical engineering has usurped the field of electro-chemistry to a large extent. We have a special course in electro-chemical engineering and have begun to feel rather at home in that subject. I confess, however, that I have my doubts concerning the legitimacy of it, and that field, even including some electrical work, belongs already, or will belong ultimately, to the chemical engineer. This follows because the major part of the information needed to carry on the work in that line is purely chemical.

Dean G. G. Pond (by letter) : The Pennsylvania State College has graduated, from its chemistry courses, about two hundred men who are actively engaged in work with a great variety of chemical industries. Some twelve years ago a considerable number of these graduates had been urging the establishment at the college, of a course calculated to turn out men, who should be trained chemists as before, but who would be better acquainted with the materials of construction and with the elements of engineering, even at the sacrifice of some chemistry, in order that they might be more capable of dealing with the problems which are likely to confront them in their various lines of occupation.

In response to this advice we inaugurated the present course, of four years, leading to the degree of bachelor of science in industrial chemistry. Our aim has been to train *chemists* primarily, and we do not regard these men as engineers. The course has been elected by a constantly increasing number of students and we feel reasonably satisfied with the results. Students regard the course as more difficult than the one which leads to the degree of bachelor of science in chemistry, and which is familiarly known as the ''straight'' chemistry course. We reluctantly sacrifice some of the strictly chemical subjects, because in no other way can we include, in a four years' term of study, the engineering topics which it has been our aim to introduce. I can not say that we have always acted wisely in the process of pruning one kind of subject and of developing the other, for there have been many places at which we could not accomplish exactly what we would like to do, and we have, therefore, had to compromise by accepting that which was available. The inexorable requirements of a "schedule" have sometimes controlled where they should not properly do so; but improvements are made from year to year, and we feel reasonably well satisfied with the course as it now stands.

Up to the present time, I have never counselled a student to elect one course in preference to the other, except in those rare instances in which a man has had in mind when a freshman, the exact line of work upon which he was almost certain to enter after graduation. I always feel very unwilling, in the case of a man who desires to become a chemist, to advise him to curtail his chemical training for the sake of the added knowledge which he will acquire in mechanical lines. Whenever possible I have advised a man to remain five years in college and complete both courses, but in no single instance has this advice been followed, nor is it likely to be in an institution where the bread-and-butter question is as strongly implanted in the mind of the undergraduate as is the case in so many of our technical colleges.

Dean Benjamin has pointed out the fact that we require a larger amount of *letters* than is demanded in other colleges, and to this I may reply that this difference between us and some of the other colleges, if not most of them, resides in the spirit of the institution. It will be found to be true of all of our technical courses and is not limited to the course in industrial chemistry. Both during the former administration and under the present executive, The Pennsylvania State College has insisted on a year each of history and of political science, two years of English and a similar amount of modern language in all courses leading to the bachelor's degree. I have no adverse criticism to make of this policy; I believe, on the whole, that it has been justified. At times it has been difficult to maintain this college policy against the pressure which must inevitably arise whenever changes are in contemplation. It holds, however, today and accounts for the peculiarity which Dean Benjamin has observed.

The shortage in the amount of chemistry which we require in this course is temporary and will be rectified with the completion of certain changes which are now under consideration.

It should not be forgotten that the men whom we train for the kind of positions which Dean Benjamin has so well described in his article should be, first of all, *chemists*. Without a thorough knowledge of the meaning of chemical equations, organic and inorganic; without the "chemical sense" which comes to most students only after long and familiar experience with chemicals and chemical apparatus; without the power to thoroughly and intimately know his raw materials and the product, which he attempts to produce, and to recognize its degree of purity, as well as the difficulties which lie in the way, no amount of engineering study will enable a chemist to go forth from college, equipped to rationally wrestle with the serious and complex problems which are sure to confront him.

Professor H. P. Talbot (by letter): The data regarding courses in chemical engineering, which Dean Benjamin has brought together, show a rather greater consensus of opinion than I should, on the whole, have anticipated. There is no doubt that our courses of instruction are still in the formative period, which is not surprising if one recalls that the chemical engineering profession itself hardly yet permits of exact definition. There can, I think, be no doubt that the larger amount of time should be devoted to chemical subjects, and I am personally of the opinion that when it is practicable to lengthen the course to five years the chemical subjects should be expanded, rather than to use a large portion of the added time for new engineering subjects. It is essential that the chemical engineer should be as thoroughly trained as a chemist as possible and if we add to this chemical training courses in engineering subjects which are as fundamental as those given to the mechanical engineers themselves, so far as they go, we have laid a safe foundation and have done about all that we can reasonably hope to do. The proportion of time to be given to Letters will, of course, vary according to the policy of individual institutions; but so long as we admit young men to these courses directly from the high schools, it is certainly desirable that as much opportunity should be given for work of this character as is possible; for the engineer of today is expected to take a share in our community life which is comparable with that of the professions formerly regarded as "learned," and he must be helped to meet these new conditions as far as practicable.

I am inclined to think that a good deal of the current criticism of engineering courses in general, and especially of chemical engineering, is not well-founded, because it does not take into consideration the extraordinary and sudden change in the position of the engineer in the community and in the demands made upon him. The men who are subjected to criticism are, in many cases, not the product of the courses in their *revised* condition, as it takes nearly seven years to try out an educational experiment. Our courses, as at present constructed, are obviously capable of improvement, but I am inclined to think that we are trending in the right direction.

Professor Alfred H. White (by letter): The chemical engineer is still largely a hybrid, as Dean Benjamin intimates, and it will take some time to fix the type. The chemical engineer is supposed to be trained to superintend manufacturing processes, and it might therefore be expected that considerable attention would be paid in the college course to the application of chemistry to manufacturing operations. The heading "Industrial Chemistry" as used by Dean Benjamin includes not only chemical technology but also the analysis of technical products. If we make a new list from the published announcements discarding the courses in analysis and retaining only those which teach manufacturing processes and methods, we get the following table of courses in chemical technology and chemical engineering:

COURSES IN CHEMICAL TECHNOLOGY AND CHEMICAL ENGINEERING.

	Hours per Week.		Thesis in Addition.
	Class.	Laboratory.	
Columbia	25	11	Yes
Wisconsin	15		Yes
Pennsylvania State	13	5	Yes
Michigan	12	15	No
Massachusetts Institute	8	7	Yes
Purdue	8		Yes
Illinois	7		Yes
University of Pennsylvania	6		No

There are a few evident discrepancies between this table and the figures for industrial chemistry given by Dean Benjamin, due doubtless to the difference in date of the published announcements at hand, but they do not materially influence the result. The differences between the schools are clearly marked. In view of the wide difference in the hours of class work it is especially interesting to note the general absence of laboratory courses in chemical technology except along special lines. The eleven hours laboratory work at Columbia are given over to textiles, electrochemistry and metallurgy. The five hours at Pennsylvania State College are devoted to electrochemistry. The fifteen hours at Michigan are a substitute for a thesis, which cannot be required under its proper name. Massachusetts Institute of Technology is the only one of the schools listed which offers a general course in preparations on the manufacturing scale. This is possibly due to lack of equipment at the other schools, but in the writer's opinion it more probably represents a deliberate judgment that it is more advisable for the student to study one problem intensively, as in thesis work, than to spend his time in trying to imitate a whole series of manufacturing operations.

CHEMICAL EDUCATION FOR THE INDUSTRIES.

BY J. H. JAMES,

Professor of Chemical Engineering, Carnegie Technical Schools.

Modern chemical manufacturing has in different branches reached its present stage of development through two entirely separate channels. The manufacture of glass, pottery, varnish, paint, iron, steel, copper, and many others, all were well established long before chemistry had emerged from the darkness of alchemy, but the knowledge upon which each of these was built was entirely empirical, entirely of the "rule of thumb." It needs no particular chemical knowledge to manufacture glass, when, for example, once the fact had been discovered, that silica, sand, lime and soda or potash heated to fusion would produce an insoluble, transparent, rigid substance, capable, while hot, of being shaped into various objects of utility. This knowledge is all empirical, and since glass is really a solid solution of several silicates, extremely wide variations are possible in the proportions of raw materials used, without the product losing the essential characteristics noted above, so that the industry developed entirely in the hands of skilled artisans who accumulated a vast amount of information in connection with its various phases.

Later, when chemistry had attained the dignity of a science we see its slow but sure influence on all such "rule of thumb" chemical industries, resulting in standardization of manufacturing methods and improvements in processes, which in many cases have been almost revolutionary in character.

There is another great field of chemical manufacture which had in its history no such evolution as noted above. I refer to those chemical manufacturing processes which are the direct outcome of the chemical research that has been carried out since chemistry became a recognized science. These processes, instead of developing by the slow more or less accidental methods of the "rule of thumb" period, were the result of laboratory research, being developed in all details on a small scale before their commercial exploitation. To this group belong the manufacture of the so-called coal-tar colors, synthetic drugs, perfumes, extracts, etc.

If, then, all branches of present day chemical manufacture are dependent more or less upon chemical science for working knowledge, has this industry rewarded the chemist as is surely his due? Confining our discussion to American conditions, it would appear that such has not been the case.

The main reason seems to be that our schools have too long been training analytical chemists, and to a lesser extent research chemists for the industries, not recognizing the fact that what the manufacturer wants in ninety per cent. of the situations offered, is a man with a combined chemical and engineering training.

The research chemist has an important place to fill in the modern industrial scheme, but in point of numbers, naturally, more operating chemists are needed; in fact, the ideas and the processes worked out by one good research chemist will keep dozens or even hundreds of operating men or chemical engineers at work, designing, installing and operating the apparatus needed for carrying out the processes on a large scale.

The important problem before the educator, in this connection, is the training of that relatively new product, the chemical engineer, as the courses and post-graduate work for students intending to follow research are already well worked out in European and American universities. A four-year course in pure and applied chemistry, without engineering, such as is offered in some American technical schools, might serve as a preparation for research work, but is not as good as the above.

Although all industries based on chemical reactions need the analytical chemist, as manufacturing methods become standardized, analytical methods as well are clearly worked out. Analytical work in most cases can be turned over to men of little training or even to boys, all working under the supervision of a trained chemist or chemical engineer, who has in addition to the analytical laboratory the supervision of operations in the plant. So, in our opinion, we should make the training in analytical chemistry incidental only to its connection with either research or operating work in industrial chemistry. Analytical chemistry is a tool to be used by the industrial chemist, just as mechanical drawing is the important tool of the mechanical engineer.

In the arrangement of the chemical engineering course about equal emphasis should be placed on chemical subjects on the one hand and engineering fundamentals on the other. Since the engineering subjects must be taught as minors in the mechanical, electrical and civil departments, the success of the chemical engineering course depends on the cooperation of these other departments. Interdepartmental jealousies and friction lower the efficiency of a school as a whole, and the injury from these causes falls with particular weight upon such a course as that of chemical engineering.

Since it is manifestly impossible to give extended training in mechanical, electrical and civil engineering in four years, together with a good chemical education, the arrangement of these minors deserves very careful consideration.

In general, it may be said that our chemical engineer's knowledge of mechanical, electrical and to a certain extent of civil engineering, can not extend any farther than the elementary principles of design, with greater stress laid on the operation and maintenance of apparatus in each field.

In the mechanical engineering minor for example, there should be given the elements of machine design, so that the student can, if necessary, design the simpler machines used in chemical manufacture. While we would not desire that our chemical engineer should be able to design a steam engine, he should be able to understand all the points involved in its care and operation. The chemical engineer is not a specialist in the design of pumps, blowers or meters, but he should have sufficient general knowledge in this field to intelligently select, order and install all such apparatus.

In like manner, the embryo chemical engineer does not take up the details of dynamo, motor and transformer design in electrical engineering, but he should have a sufficient knowledge, for example, of electrical machinery, to order the proper dynamos, transformers and connections for an electric furnace installation required for carrying out a certain electro-thermal reaction on a large scale.

Invaluable, in the training of the chemical engineer, is a course in shop management, when the school in question is fortunate enough to have a competent man on the faculty, who has had practical experience in industrial systematization.

This leads to the thought that the men giving instruction on the chemical staff, and in the various engineering subjects, should be identified with the industries of the locality. This is particularly applicable to the chemical profession, since here, deplore it as we may, there exists a great deal of the foolish harboring of secrets that characterized the old alchemical days, which prevents the publication of improvements in apparatus and processes for years and years. The professor of applied chemistry and chemical engineering who depends on published books and periodicals for information for his lectures will be teaching practice that is twenty years behind the times. He should have a wide acquaintance among men in chemical engineering and should be allowed to have his schedule arranged so that from one third to one half of his time is available for consulting work that will bring him in close touch with one or more live chemical industries.

With coöperation in the teaching of the engineering minors as noted above, and with men of strong personality on the chemical staff of an institution, who love equally well their teaching and consulting work, the student of chemical engineering will have created for him an interest in his profession that will carry him forward to a successful career.

DISCUSSION.

Professor M. C. Whitaker (by letter): Professor James's definition of a chemical engineer conforms exactly to the views I have been holding, but for some strange reason many of our most prominent educators persist in confusing the function of the chemical engineer with those of the research chemist or even the analytical chemist. As a result of this lack of clear definition at the outset, the discussions on the education of chemists soon become involved and, at times, footless.

There is a great field for factory operating chemists. No existing engineering training will fit a man for the operating manager of the average manufacturing process as well as a properly planned course in chemical engineering, because most manufacturing operations involve, at some stage or other, chemical practice. This chemical work is not necessarily research. These men are not there to develop new chemistry but to use old chemistry and keep it going. The problems they have to confront come about as the results of natural variation in raw materials, variation in practice or process, or variation in results desired but their pivotal point is always chemical. The average engineering graduate has only a ''flirting'' knowledge of chemistry and therefore finds even these simple problems beyond his knowledge. Hence the need and the demand for chemical engineers who can operate chemical processes.

I belive that chemistry, physics and allied sciences should be made the focal points of the chemical engineer's training. Electrical, mechanical and all engineering subjects should be grouped around these fundamentals, always keeping in mind that the chemist is interested in pumps, engines and motors from the standpoint of operation and not necessarily from the standpoint of design and construction.

The chemical engineer is even more than a man who has combined a training in chemistry with a training in other engineering branches. His training should include not only the training in the fundamentals of physics, chemistry, etc., followed by the engineering branches, but should be supplemented by courses designed to show the student *how to apply* his knowledge to industrial problems, just as a medical student goes to a hospital to be trained in the application of his knowledge, while still under the control of his teacher. Such a course in chemical engineering could not be covered in four years and I know of no reason why student or instructor should expect to master such a difficult problem in such a short time. If we need the product—chemical engineer—we should take time to make it and make it right. Manufacturers do not want ''near trained'' engineers for their responsible positions and I believe they will welcome an opportunity to pay the price if we show good goods.

Professor J. R. Withrow (by letter): In discussing this paper I think it is well to emphasize that there is unquestionably room in the chemical industries for both the research and so-called works chemist, as well as the analytical or routine laboratory chemist. I have seen from time to time statements made by men of undoubted eminence that either one or other of the first two kinds of chemists is unnecessary. The statement has been made that all that was necessary was research, meaning laboratory or pure research, overlooking entirely the fact that efficiency maintenance is probably the most important problem in manufacturing of all kinds and that the chemist is becoming more and more a vital factor in this part of manufacture. On the other hand one hears perhaps more commonly the statement made that a man must be a chemical engineer to be a success industrially. That this is not true entirely is shown by the healthy growth of the establishment of research laboratories in the various industries of the country. However, it must be stated that it is undoubtedly true in the present state of development of chemical industries that the most important thing is not the revolutionizing of the present industries but the maintaining and increasing their present efficiency.

With regard to the cooperation between the engineering departments and chemical departments in carrying out a four year course in chemical engineering, some things have been done in various places and we hope much more will be done. At Ohio State University we have made a slight beginning at least, by a general cooperation on the part of the Department of Engineering Drawing with the course in Industrial Chemistry so that the old course in technical drawing, which was given to junior chemical engineers and which involved the preparation of plans and specifications for the construction of a building, has now been turned into a course where the building project is the housing for a definite portion of some industrial chemical manufacture. For instance in the present year the first problem taken up was the preparation of drawings for a filter press which was in actual operation in the industrial chemical laboratory. This involved a thorough understanding of the operation and construction of the filter press as well as the drafting technique necessary for the preparation of working drawings. The next problem taken up was that involving the designing of a piping system. The particular problem was the caustisizing of sodium carbonate by means of lime in a suitable digester, all liquid materials to be handled by the same pump. These complete and somewhat complicated arrangements introduced the students to the problems involved and the apparatus available for working out piping problems. These two problems are preliminary to the final problem of the year which will be the preparation of drawings for the construction of a water softening tower. The work is carried on by both departments, the chemistry being explained by the professor of industrial chemistry, and the mechanical details being taken care of by the mechanical engineer in charge of the drawing work and the work of the students is criticized by both men travelling together usually but not necessarily so. In different years we have taken up different problems covering such cases as nitric acid, naphthalene, ferrous sulphate-pickel liquor plants, etc.

It has been well said by Dr. James that a chemical engineer is not a specialist in the design of pumps and other machinery, but he should be familiar with what must be known or done to accomplish a given engineering result or overcome a given difficulty and also know how to tackle a problem when he meets it.

Emphasis has been laid from time to time in the discussion of this general topic, upon the fact that a man giving instruction in applied chemistry should be connected with the industries of his locality or at least actually connected with some industry. This beyond question has its academic difficulties and at times causes dissatisfaction among members of the instruction force in other lines who are not able or who have no opportunity for such connections. Any one however who has had to teach industrial chemistry, having had personal manufacturing experience will realize better than he can tell what this experience is worth to him in the carrying on of his work, because the professor of applied chemistry or chemical engineering who is compelled to depend in large measure upon publications or hearsay or even mere visits to factories, is at a disadvantage that is beyond computation. Usually a man who lays out this kind of work is not allowed enough leeway to properly develop it. He is usually tied to some energy absorbing course as a mere assistant. The work is looked upon as a new thing in chemical instruction and may be turned over to any young doctor who is just out of the laboratory or else to one of the professors who may have had experience in teaching other branches but who has not the works point of view nor is given the time to develop a field which includes all others and therefore takes more energy than any other branch of chemistry to build it up, with satisfaction.

REPORT ON ENTRANCE REQUIREMENTS AND DEFINITION OF SUBJECTS PRESENTED BY COMMITTEE ON ENTRANCE REQUIREMENTS.

To the Society for the Promotion of Engineering Education:

Your Committee on Entrance Requirements herewith presents the following report:

DEFINITION OF UNIT.

A unit course or credit required for entrance is understood as representing work equivalent to that covered in a school year of thirty-six weeks, five periods per week, each period not less than forty minutes in the clear: this includes an aggregate of one hundred and twenty 60-minute hours of class room work. It is further understood that two periods of laboratory, or manual training (including drawing) is equivalent to one period of class room work.

Following the standard established by the Carnegie Foundation for the Advancement of Teaching, fourteen units will constitute the minimum amount of preparation which may be accepted for entrance.

If in the aggregate four studies be pursued each year for a period of four years it will be possible to qualify in sixteen units; a unit therefore constitutes practically one fourth of a year's work.

The selection of subjects which will be accepted for entrance should be to a certain extent left to the individual colleges, but there exists a marked tendency toward uniformity of requirement with certain studies and a fair degree of freedom regarding the remainder of the subjects. This your committee believes to be right but desires to emphasize the danger in too great freedom in the choice of electives.

In a previous report of the committee (see Vol. IV.) it was stated that: "The committee regards absolute uniformity of requirements as entirely inconsistent with the diversity of educational conditions in different states, and as not in itself desirable.

"Needless arbitrary deviations from uniformity in mere details are vexatious and harmful to all concerned and should be removed as soon as possible by coöperation between colleges and schools.

To secure such degree of uniformity as is practicable, the committee recommended a definite list of entrance requirements somewhat as follows:

Mathematics.

Arithmetic (complete).
Algebra, elementary.
Algebra, through quadratics.
Algebra advanced.
Geometry, plane.
Geometry, solid.
Trigonometry, plane.

Science.

Physical geography.
Botany.
Chemistry.
Physics.

Language.

English.
French.
German.
Latin.

General.

Free hand drawing.
United states history.
Some second subject in history.

It may be remembered that the list of studies actually required for admission to technical colleges at the time the former report was written included a large number of subjects, among which we note:

"Writing, reading, partial arithmetic, mensuration, elementary mechanics, higher mathematics, civil government, local government, bookkeeping, elocution, mental science, logic, economics, theory of teaching, Milne's "Realm of Nature," zoölogy, astronomy, geology, mineralogy, meteorology, natural history, biology, introduction to science, etymology, Latin elements of English, Spanish and Greek. This diversity crept in to some extent, no doubt, through the attempt on the part of the colleges to meet the varying courses of their contributory schools through a system of options in requirements, and possibly, to make the scientific courses level up to the classical ones without the necessity of imposing the dead languages on the student. But the effect was to scatter and produce confusion on the one hand, and to limit each college to its own field of cultivated schools on the other."

The report states further:

"There is enough within the above list, that so many colleges agree upon, to fully occupy the time of any boy in his four years in the high school, and there is variety enough to give breadth of training. There is work in the five chief lines of mathematics, language and literature, history, science and art. Any school course, on the one hand, and any college set of requirements, on the other, ought to include all of these lines.

"Again, while the colleges should confine themselves to the above subjects, there is nothing in the list that does not properly fit into the school curriculum. Laboratory work of the right kind in physics, chemistry and botany may be found in comparatively few schools, but it ought to be given in all high schools with four-year courses, for their own sakes, irrespective of the demands of scientific colleges.

"Somewhat apart from the other subjects named, stands manual training, including shop work and mechanical drawing.

"It is obviously impossible—even if desirable—to make either of these a requirement for admission to engineering colleges generally. On the other hand, the engineering colleges should be the first to recognize the true value of hand and eye work as a form of education. The committee believes that, so far as practicable, such recognition should be more generally shown by the acceptance of certified work in manual training as an optional requirement by institutions accepting any optional subjects."

It is very gratifying to note the change that has taken place since the report quoted was presented. With few exceptions the list of subjects proposed at that time includes the essential requirements now accepted for admission to most of the technical colleges of the country. There has been a marked co-operation between the colleges and secondary schools which has tended toward the establishment of certain standards, both in the kind and character of subjects taught. Of the fourteen or fifteen units required for admission the colleges have demanded preparation in definite prescribed subjects amounting to about one half the total work, while the remainder may be selected from a list sufficiently comprehensive to allow the secondary schools considerable freedom in establishing their courses. Nor does this detract from the intellectual development of those in the secondary schools who do not enter college, since there is general agreement as to the value of the prescribed courses in any scheme of secondary education.

Referring to the list quoted above it will be noted that arithmetic is not, in general, now accepted as an entrance subject; on the other hand, on account of the commercial interests of the United States there has grown up a demand for the study of Spanish in the public schools and this subject should be added to the language group.

Zoölogy is frequently studied in the secondary schools instead of botany, and this subject should be included in the science group.

In many well-organized secondary schools the study of history is pursued for the entire four years and the general group should be modified by adding the four history subjects most commonly taught, or preferably, a new history group should be introduced: This should include ancient history; medieval and modern European history; English history; American history or American history and civil government.

The general introduction of manual training (shop work and drawing) into the secondary schools has caused a number of colleges, both academic and technical, to accept a certain amount of this work in lieu of other subjects for entrance. Shop work and mechanical drawing should therefore be offered in the list of electives acceptable to the engineering college.

Your committee recognizes that there will necessarily be differences of opinion as to the amount of credit which can be accepted for entrance by the college for manual training subjects, but substantial agreement will probably exist if the credit be restricted to one unit for shop work and one unit for drawing.

However, with the credits thus restricted it must be pointed out that in order to qualify in fourteen units as specified, a student taking work in manual training must either limit the amount of this work, or he must take other studies additional to the manual training subjects.

A restriction should also be placed on the language group: That is, if a language be offered for entrance two units should be presented for any one language. This will tend to prevent that "browsing around" which is both harmful and pernicious.

The modified list of subjects among which are to be found the entrance requirements for engineering colleges would then be as follows:

Mathematics.

Algebra, elementary.
Algebra, advanced.
Geometry, plane.
Geometry, solid.
Trigonometry, plane.

Science.

Physics.
Chemistry.
Botany.
Zoology.
Physical geography.

Language.

English.
French.
German.
Spanish.
Latin.

History.

Ancient.
Modern European.
English.
American.

General.

Manual training. Shop work.
Mechanical drawing.
Free-hand drawing.

The prescribed subjects taken from the above list should include:

Algebra, elementary	One unit.
Geometry, plane	One-half unit.
Algebra, advanced	One unit.
Geometry, solid	One-half unit.
English	Three units.
One other language	Two units.
or physics or chemistry	One unit.

Total prescribed subjects eight units or seven units.

DEFINITION OF REQUIREMENTS.

MATHEMATICS.

The definitions of requirements in mathematics are, with slight modifications, essentially the same as those formulated by the Committee on Mathematics of the North Central Association of Colleges and Secondary Schools presented at the Chicago meeting, March, 1910.

A. Three chief aims should be set for instruction in mathematics: (1) To inspire and facilitate the acquisition of knowledge in an important field. (2) To develop the ability to apply this knowledge to practical and theoretical investigations. (3) To develop and strengthen the ability to perceive exact relations and to make inferences correctly; the teacher's constant aim should be to train the pupil to think and to formulate clearly the results of his thinking.

B. Students completing a high school course and presenting themselves for admission to college should show: (1) A fair degree of accuracy and rapidity in calculation. (2) A fair degree of skill in making algebraic transformations. (3) The ability to use the equation as an instrument in the solution of problems. (4) The ability to interpret algebraic results. (5) A fair comprehension of what constitutes a proof in mathematics. (6) A good knowledge of the facts of elementary algebra, and plane and solid geometry.

C. Students during the last high school year, because of their greater maturity, have much more ability to grasp the abstract thinking of mathematics than do students of the earlier years. The material offered in the courses and the methods of instruction should be determined with this in view. At first the simpler and more concrete ideas of the subject should be dealt with. In later stages, more complicated mechanical work and formal theory should be introduced gradually.

It is strongly urged by your committee that the study of mathematics in preparatory schools be encouraged throughout the last school year.

It is becoming more and more evident that a change in the arrangement of the subject matter involved is desirable.

Under any arrangement, arithmetic, algebra, geometry and trigonometry should be regarded and treated as different phases of one and the same subject. The geometrical, the arithmetical, algebraic and physical phases of mathematics should be presented as far as possible from the beginning to the end of the secondary course. Much can be done in this direction by employing geometrical methods in algebra and by using algebraic processes in geometry. Numerous examples taken from physics, and problems illustrated graphically taken from any source whatever may be advantageously employed.

ALGEBRA 1a AND 1b.

FORMULATION I.—One and a half units.

The algebra required for entrance to college should include the following topics (no significance to be attached to the order given here): (1) The fundamental laws of algebra. (2) The general view of algebraic number. (3) The four fundamental operations as applied to integral, fractional and irrational expressions. (4) Factoring. (5) Binomial theorem for positive integral exponents. (6) Solution of equations in one variable including simple quadratic, fractional and irrational equations. (7) Solution of systems of equation in two variables; including linear system, linear-quadratic system and a few of the quadratic systems that occur more frequently in practise. (8) Ratio and proportion. (9) The statement and solution of problems.

It is recommended that this unit and a half be divided into two portions, an elementary course, Algebra 1a, to be given in the first year of high school and a more advanced course to be given after the course in plane geometry in the third or fourth year.

The following suggestions are made as to the character of these courses.

Algebra 1a should deal with the simpler portions of the topics named, with the exception of the greater portion of 7, which should be treated in Algebra 1b.

Omit complicated forms of parentheses, fractions, irrationals, types of factoring and equations. The aim should be a training in algebra as a method of thinking rather than as an exercise in the manipulation of complicated expressions. Ideas and methods should grow out of the pupils' knowledge of arithmetic and the relations of common experience. The traditional order of topics is not to be commended. Emphasis should be placed on the equation as a means of solving problems, other topics contributing assistance as the need arises. The equation should be used at the very beginning, as it is of paramount importance throughout the course.

The second course, Algebra 1b, should be a more systematical and scholarly consideration of the ground already covered and an extension of ideas to more complicated expressions. By the time the student has finished this course he should have acquired that facility in the use of algebraic expressions which is so essential to the further study of mathematics. A mastery of the fundamentals of theory and practise must be insisted upon.

PLANE GEOMETRY, 2.

Formulation II.—One unit.

The usual theories and constructions of good text-books, including the general properties of plane rectilinear figures; the circle and the measurement of angles; similar polygons; areas; regular polygons and the measurement of the circle.

The solution of numerous original exercises, including loci problems.

Applications to the mensuration of lines and plane surfaces.

In plane geometry it is suggested that a clearer conception of geometrical reasoning and a firmer grasp upon geometrical facts can be acquired by a thorough consideration of a small number of theorems than by a hurried glance at a larger number. It is therefore recommended that the more important theorems be emphasized and that the less important theorems be omitted or passed over without proof. It is suggested that teachers be free to assume the truth of some of the most evident theorems at first. Proof may be given later if desired. The original demonstration of theorems is of the utmost importance. The use of exercises involving algebraic and numerical applications is to be encouraged. The habit of giving accurate definitions, the perception of what constitutes a demonstration of truth, confidence in one's own power of correct reasoning and the ability to discover geometrical relations are of more importance than the ability to recall the demonstration of a large number of theorems. It would be well to omit the theory of limits and incommensurables from this course.

SOLID GEOMETRY, 3.

Formulation III.—One half unit.

Solid geometry should comprise the usual topics given in texts, including the relations of planes and lines in space; the properties and measurement of prisms, pyramids, cylinders and cones; the sphere and the spherical triangle.

The solution of numerous original exercises, including loci problems.

Here too, there should be a centering of attention upon the more important theorems. More emphasis should be placed on mensuration.

It may be desirable in some schools to re-arrange the material of courses 2 and 3 so that course 2 should include the elements of both plane and solid geometry, leaving to course 3 the more difficult phases of the subject.

PLANE TRIGONOMETRY.

FORMULATION IV.—One half unit.

If plane trigonometry be offered it should include the definitions and relations of the six trigonometrical functions as ratios, the theory of logarithms, and use of tables, the proof of important formulae, the solution of right and oblique triangles, and considerable practise in trigonometric transformations.

PHYSICS.

The requirement in physics based on the report of the Committee on Physics of the Science Department of the National Educational Association appears to be too comprehensive for the average high school, in fact, it has been stated that only three or four high schools of the country are in a position to teach the physics as outlined in the above report and your committee believes that the number of required topics should be reduced so as to more nearly meet the existing conditions as found in the average high school throughout the country.

FORMULATION V.—One unit.

It is recommended that the candidate's preparation in physics should include:

1. The study of at least one standard text-book, supplemented by the use of numerical problems, ''to the end that the pupil may gain a concise and connected view of the most important facts and laws in elementary physics.''

2. Individual laboratory work comprising at least twenty-five exercises selected from a list of fifty or more, not very different from the list given below.

3. Instruction by lecture-table demonstrations to be used mainly as a basis for questioning upon the general principles involved in the pupil's laboratory investigations.

The time devoted to this subject should be not less than one year of five periods per week. At least one fourth of the time must be devoted to laboratory work, which should consist of double periods of not less than 80 minutes each. Thoroughness and intelligent methods are desired rather than a fund of information.

The following list of suggested topics has been prepared by the Committee on Definition of Physics of the North Central Association of Colleges and Secondary Schools. It includes all those topics which are essential to an elementary course in physics, but it is not intended to restrict the teacher to the list here presented, since individual environment may demand modification.

1. Weight, center of gravity.
2. Density.
3. Parallelogram of forces.
4. Atmospheric pressure; barometer.
5. Boyle's law.
6. Pressure due to gravity in liquids with a free surface; varying depth, density, and shape of vessel.
7. Buoyancy; Archimedes' principle.
8. Pascal's law; hydraulic press.
9. Work as force times distance, and its measurement in foot-pounds and gram-centimeters.
10. Energy measured by work.
11. Law of machines: work obtained not greater than work put in; efficiency.
12. Inclined plane.
13. Pulleys, wheel and axle.
14. Measurement of moments by the product of force times arm; levers.
15. Thermometers: Fahrenheit and Centigrade scales.
16. Heat quantity and its measurement in gram calories.
17. Specific heat.

18. Evaporation; heat of vaporization of water.
19. Dew point; clouds and rain.
20. Fusion and solidification; heat of fusion.
21. Heat transference by conduction and convection.
22. Heat transference by radiation.
23. Qualitative description of the transfer of energy by waves.
24. Wave-length and period of waves.
25. Sound originates at a vibrating body and is transmitted by waves in air.
26. Pitch and period of sound.
27. Relation between the wave length of a tone and the length of a string or organ pipe.
28. Resonance.
29. Beats.
30. Rectilinear propagation of light; pin-hole camera.
31. Reflection and its laws; image in a plane mirror.
32. Refraction, and its use in lenses; the eye, the camera.
33. Prisms and dispersion.
34. Velocity of light.
35. Magnetic attractions and repulsions.
36. Field of force about a magnet.
37. The earth a magnet; compass.
38. Electricity by friction.
39. Conductors and insulators.
40. Simple galvanic cell.
41. Electrolysis; definition of the ampere.
42. Heating effects; resistance; definition of the ohm.
43. Ohm's law; definition of the volt.
44. Magnetic field about a current; electromagnets.
45. Electromagnetic induction.
46. Simple alternating current dynamo of one loop.
47. Electromagnetic induction by breaking a circuit; primary and secondary.
48. Conservation of energy.

At the time of the examination the candidate must present a note-book in which he has recorded the steps and the results of his laboratory exercises, and this note-book must bear the endorsement of his teacher, certifying that the notes are a true record of the pupil's work. It should contain an index of the exercises which it describes. It is practicable for pupils to make the original record of their observations entirely presentable, so that copying will be unnecessary, and they should in general be required to do so.

CHEMISTRY.

The requirement in chemistry is based on the report of the Committee on Chemistry of the Science Department of the National Educational Association and is subject to the same criticism which has been made regarding the definition for physics. The criticisms on this requirement given by the various professors of chemistry in the technical colleges indicate that the high schools are attempting to teach college courses without proper equipment and facilities and that it would be better to have a less comprehensive course which could be well taught in the average high school than to attempt to cover so much ground which at best can be accomplished only superficially in the average high school. With this in view, the following formulation is offered as a definition of the requirement in chemistry.

FORMULATION VI.—One unit.

The following outline includes only the indispensable things which must be studied in the class-room and laboratory. The material is, for the most part, common to all elementary text-books and laboratory manuals. Each book makes its own selection of facts beyond that which may be necessary for the illustration of the principles of the science. The order of presentation will naturally be determined by each teacher for himself.

Outline.—The chief physical and chemical characteristics, the preparation and the recognition of the following elements and their chief compounds: oxygen, hydrogen, carbon, nitrogen, chlorine, bromine, iodine, fluorine, sulphur, phosphorus, silicon, potassium, sodium, calcium, magnesium, zinc, copper, mercury, silver, aluminum, lead, tin, iron, manganese, chromium.

More detailed study should be confined to a restricted list of compounds, such as water, hydrochloric acid, chlorine, sodium hydroxide, and sodium carbonate.

Attention should be given to the atmosphere (constitution and relation to animal and vegetable life), flames, acids, bases, salts, oxidation and reduction, crystallization, manufacturing processes, familiar substances (illuminating gas, explosives, baking powder, mortar, glass, metallurgy, steel, common alloys, porcelain, soap).

Combining proportions by weight and volume; calculations founded on these and Boyle's and Charles' law; symbols and nomenclature (with careful avoidance of special stress, since these are non-essential); atomic theory, atomic weights and valency in a very elementary way; nascent state; natural grouping of the elements; solution (solvents and solubility of gases, liquids and solids, saturation); strength (=activity) of acids and bases; conservation and dissipation of energy; chemical energy (very elementary); electrolysis. Chemical terms should be defined and explained, and the pupil should be able to illustrate and apply the ideas they embody. The theoretical topics are not intended to form separate subjects of study, but to be taught only so far as is necessary for the correlation and explanation of the experimental facts.

It is recommended that the candidate's preparation in chemistry should include:

1. The study of at least one standard text-book to the end that the pupil may gain a comprehensive and connected view of the most important facts and laws of elementary chemistry.

2. Individual laboratory work comprising at least twenty-five exercises selected from a list of fifty or more, not very different from the list given below.

3. Instruction by lecture-table demonstrations to be used mainly as a basis for questioning upon the general principles involved in the pupil's laboratory investigations.

The time devoted to this subject should be not less than one year of five periods per week, of which at least one third should be spent in laboratory work. All laboratory periods should be double and consist of not less than 80 minutes each.

LIST OF EXPERIMENTS.

GENERAL.

1. Composition of the atmosphere.
2. Dissociation of mercuric oxide, and study of resulting products.
3. Burning of magnesium and sodium in air, and of iron in oxygen, with study of resulting products.
4. Burning of sulphur and phosphorus in air; study of products.
5. Treatment of substances resulting from (3) with hydrochloric acid, and examination of final products.

Laws of Gas Volumes and Vapor Tension.

6. Boyle's Law.
7. Charles' Law.
8. Vapor tension.

Common Elements and Compounds.

9. Preparation and study of oxygen.
10. Liberation of hydrogen by action of sodium on water. Careful study of by-product.
11. Preparation of hydrogen by zinc and acid. More thorough study of hydrogen in larger quantities; study of by-product.
12. Proportion of volume in which hydrogen and oxygen unite. (Lecture demonstration with eudiometer.)
13. Proportion by weight in which hydrogen and oxygen combine. (Lecture experiment.)
14. Change of boiling point and freezing point as affected by concentration.
15. Taste of substance produced by combining oxygen and hydrogen; action on litmus.

16. Electrolysis of water, resulting gases being accurately measured and tested.
17. Study of sodium, potassium, strontium, calcium and barium compounds.
18. Study of soda processes.
19. Study of salts of cobalt, copper, nickel, manganese, chromium, iron.
20. Study of compounds of aluminum, magnesium and zinc.
21. Preparation and study of chlorine gas.
22. Combustion of chlorine in hydrogen.
23. Preparation of hydrochloric acid and study of properties.
24. Preparation and study of at least three chlorides.
25. Preparation and study of bromine.
26. Preparation of at least three bromides.
27. Preparation and study of iodine.
28. Preparation of at least three iodides.
29. Study of hydrofluoric acid and fluorides.
30. Study of forms of sulphur.
31. Direct formation of sulphides.
32. Study of sulphurous oxide.
33. Preparation of sulphurous and sulphuric acids.
34. Preparation of at least two sulphites and two corresponding sulphates. Comparative study of these.
35. Decomposition of ammonium nitrate and study of nitrous oxide.
36. Preparation and study of nitric acid.
37. Preparation of three nitrates in three different ways.
38. Composition of gas formed by action of cold dilute nitric acid on copper.
39. Composition of gas formed by union of nitric oxide and oxygen.
40. Preparation of ferrous and ferric salts.
41. Stability of salts on heating dry.

Carbon and some Carbon Compounds.

42. Product of burning charcoal. Tests.
43. Test for presence of carbon in wood, paper, kerosene, coal gas, alcohol.

44. Preparation of three carbonates.
45. Solubility of carbonates in the presence of carbon dioxide.
46. Effect of heat on suspension of carbonates in solution.
47. Carbon dioxide from fermentation.

A knowledge of the more important chemical industries, and ability to work simple problems will be required.

At the time of the examination the candidate must present a note-book in which he has recorded the steps and the results of his laboratory exercises, and this note-book must bear the endorsement of his teacher, certifying that the notes are a true record of the pupil's work. It should contain an index of the exercises which it describes. It is practicable for pupils to make the original record of their observations entirely presentable, so that copying will be unnecessary, and they should in general be required to do so.

The following notes taken from the report of the Committee on Definition of Requirement in Chemistry, North Central Association of Colleges and Secondary Schools, are worthy of careful attention.

"Disregarding questions of order, and simply classifying the essential principles of instruction, the pupil should be taught:

"1. Technique of experimentation.

"Properties of common apparatus in respect to structure and material. For example, how to make an apparatus air-tight and why. Object of such operations as washing and drying gases and how the object is attained.

"Physical properties which may be used for recognition of each substance and for explanation of all observations.

"Judicious use of properties and materials. Influence of conditions (temperature, homogeneous and heterogeneous mixture, etc.) on chemical change.

"2. Physical phenomena, their recognition, description and physical interpretation.

"3. The more strictly chemical application of the results. For example, inference in regard to the nature of the chemical change which must have led to the results observed. Making of the chemical equation from adequate data."

ENGLISH.

The requirement in English is that recommended by the Conference on Uniform Entrance Requirements in English for the years 1913, 1914 and 1915.

FORMULATION VII.—Three units.

Preparation in English has two main objects. (1) command of correct and clear English, spoken and written; (2) ability to read with accuracy, intelligence, and appreciation.

The first object requires instruction in grammar and composition. English grammar should ordinarily be reviewed in the secondary school; and correct spelling and grammatical accuracy should be rigorously exacted in connection with all written work during the four years. The principles of English composition governing punctuation, the use of words, paragraphs, and the different kinds of whole composition, including letter writing, should be thoroughly mastered; and practice in composition, oral as well as written, should extend throughout the secondary school period. Written exercises may well comprise narration, description, and easy exposition and argument based upon simple outlines. It is advisable that subjects for this work be taken from the student's personal experience, general knowledge, and studies other than English, as well as from his reading in literature. Finally, special instruction in language and composition should be accompanied by concerted effort of teachers in all branches to cultivate in the student the habit of using good English in his recitations and various exercises, whether oral or written.

The second object is sought by means of two lists of books, headed respectively *reading* and *study,* from which may be framed a progressive course in literature covering four years. In connection with both lists, the student should be trained in reading aloud and be encouraged to commit to memory some of the more notable passages both in verse and in prose. As an aid to literary appreciation, he is further advised to acquaint himself with the most important facts in the lives of the authors whose works he reads and with their place in literary history.

a. Reading.—The aim of this course is to foster in the student the habit of intelligent reading and to develop a taste for good literature, by giving him a first-hand knowledge of some of its best specimens. He should read the books carefully, but his attention should not be so fixed upon details that he fails to appreciate the main purpose and charm of what he reads.

With a view to large freedom of choice, the books provided for reading are arranged in the following groups, from which at least ten units* are to be selected, two from each group:

I. The Old Testament, comprising at least the chief narrative episodes in Genesis, Exodus, Joshua, Judges, Samuel, Kings, and Daniel, together with the books of Ruth and Esther; the Odyssey, with the omission, if desired, of Books I., II., III., IV., V., XV., XVI., XVII.; the Iliad, with the omission, if desired, of Books XI., XIII., XIV., XV., XVII., XXI.; Vergil's Æneid. The Odyssey, Iliad, and Æneid should be read in English translations of recognized literary excellence.

For any unit of this group a unit from any other group may be substituted.

II. Shakspere's Merchant of Venice; Midsummer Night's Dream; As You Like It; Twelfth Night; Henry the Fifth; Julius Cæsar.

III. Defoe's Robinson Crusoe, Part I.; Goldsmith's Vicar of Wakefield; either Scott's Ivanhoe or Scott's Quentin Durward; Hawthorne's House of the Seven Gables; either Dicken's David Copperfield, or Dickens' Tale of Two Cities; Thackeray's Henry Esmond; Mrs. Gaskell's Cranford; George Eliot's Silas Marner; Stevenson's Treasure Island.

IV. Bunyan's Pilgrim's Progress, Part I.; The Sir Roger De Coverley Papers in the Spectator; Franklin's Autobiography (condensed); Irving's Sketch Book; Macaulay's Essays on Lord Clive and Warren Hastings; Thackeray's

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* Each unit is set off by semicolons.

English Humorists; Selections from Lincoln, including at least the two Inaugurals, the Speeches in Independence Hall and at Gettysburg, the Last Public Address, and Letter to Horace Greeley, along with a brief memoir or estimate; Parkman's Oregon Trail; either Thoreau's Walden or Huxley's Autobiography and selections from Lay Sermons, including the addresses on Improving Natural Knowledge, A Liberal Education, and A Piece of Chalk; Stevenson's Inland Voyage and Travels With a Donkey.

V. Palgrave's Golden Treasury (First Series), Books II. and III., with especial attention to Dryden, Collins, Gray, Cowper, and Burns; Gray's Elegy in a Country Churchyard and Goldsmith's Deserted Village; Coleridge's Ancient Mariner and Lowell's Vision of Sir Launfal; Scott's Lady of the Lake; Byron's Childe Harold, Canto IV., and Prisoner of Chillon; Palgrave's Golden Treasury (First Series), Book IV., with special attention to Wordsworth, Keats, and Shelley; Poe's Raven, Longfellow's Courtship of Miles Standish, and Whittier's Snow-Bound; Macaulay's Lays of Ancient Rome and Arnold's Sohrab and Rustum; Tennyson's Gareth and Lynette, Lancelot and Elaine, and The Passing of Arthur; Browning's Cavalier Tunes, The Lost Leader, How They Brought the Good News from Ghent to Aix, Home Thoughts from Abroad, Home Thoughts from the Sea, Incident of the French Camp, Hervé Riel, Pheidippides, My Last Duchess, Up at a Villa—Down in the City.

b. Study.—This part of the requirement is intended as a natural and logical continuation of the student's earlier reading, with greater stress laid upon form and style, the exact meaning of words and phrases, and the understanding of allusions. For this close reading are provided a play, a group of poems, an oration, and an essay, as follows:

Shakspere's Macbeth; Milton's L'Allegro, Il Penseroso, and Comus; either Burke's Speech on Conciliation with America, or both Washington's Farewell Address, and Webster's First Bunker Hill Oration; either Macaulay's Life of Johnson, or Carlyle's Essay on Burns.

However accurate in subject matter, no paper will be considered satisfactory if seriously defective in punctuation, spelling, or other essentials of good usage.

The examination will be divided into two parts, one of which may be taken as a preliminary, and the other as a final.

The first part of the examination will be upon ten units chosen, in accordance with the plan described earlier, from the lists headed *reading;* and it may include also questions upon grammar and the simpler principles of rhetoric, and a short composition upon some topic drawn from the student's general knowledge or experience. In grammar and rhetoric, the candidate may be asked specific questions upon the practical essentials of these studies, such as the relation of the various parts of a sentence to one another, the construction of individual words in a sentence of reasonable difficulty, and those good usages of modern English which one should know in distinction from current errors. On the books prescribed for reading, the form of the examination will usually be the writing of short paragraphs on several topics which the candidate may choose out of a considerable number. These topics will involve such knowledge and appreciation of plot, character development and other qualities of style and treatment as may be fairly expected of boys and girls.

The second part of the examination will include composition and those books comprised in the list headed *study.* The test in composition will consist of one or more essays, developing a theme through several paragraphs; the subjects will be drawn from the books prescribed for *study,* from the candidate's other studies, and from his personal knowledge and experiences quite apart from reading. For this purpose the examiner will provide several subjects, perhaps five or six, from which the candidate may make his own selections. The test on the books prescribed for study will consist of questions upon their content, form, and structure, and upon the meaning of such words, phrases, and allusions as may be necessary to an understanding of the works and an appreciation of their salient qualities of style. General questions may also be asked concerning the lives of the authors, their other works, and the periods of literary history to which they belong.

It is strongly urged by your committee that the study of English in preparatory schools be encouraged throughout the last school year.

FRENCH.

The definitions of the requirements in French follow the recommendations of the Committee of Twelve of the Modern Language Association.

FORMULATION VIII.—Two units.

a. The Elementary Requirement.

The Aim of the Instruction.—At the end of the elementary course the pupil should be able to pronounce French accurately, to read at sight easy French prose, to put into French simple English sentences taken from the language of everyday life, or based upon a portion of the French text read, and to answer questions on the rudiments of the grammar as defined below.

The Work to be Done.—During the first year the work should comprise: (1) Careful drill in pronunciation; (2) the rudiments of grammar, including the inflection of the regular and the more common irregular verbs, the plural of nouns, the inflection of adjectives, participles, and pronouns; the use of personal pronouns, common adverbs, prepositions, and conjunctions; the order of words in the sentence, and the elementary rules of syntax; (3) abundant easy exercises, designed not only to fix in the memory the forms and principles of grammar, but also to cultivate readiness in the reproduction of natural forms of expression; (4) the reading of from 100 to 175 duodecimo pages of graduated texts, with constant practice in translating into French easy variations of the sentences read (the teacher giving the English), and in reproducing from memory sentences previously read; (5) writing French from dictation.

During the second year the work should comprise: (1) the reading of from 250 to 400 pages of easy modern prose in the form of stories, plays, or historical or biographical sketches; (2) constant practise, as in the previous year, in translating into French easy variations upon the texts read; (3) frequent abstracts, sometimes oral and sometimes written, of portions of the text already read; (4) writing French from dictation; (5) continued drill upon the rudiments of grammar, with constant application in the construction of sentences; (6) mastery of the forms and use of pronouns, pronominal adjectives, of all but the rare irregular verb forms, and of the simpler uses of the conditional and subjunctive.

Suitable texts for the second year are: About's Le roi des Montagnes, Bruno's Le tour de la France, Daudet's easier short tales, La Bedolliere's La Mere Michel et son chat, Erckmann-Chatrian's stories, Foa's Contes biographiques and Le petit Robinson de Paris, Foncin's Le pays de France, Labiche and Martin's La poudre aux yeux and Le voyage de M. Perrichon, Legouve and Labiche's La cigale chez les fourmis, Malot's Sans famille, Mairet's La tache du petit Pierre, Merimee's Colomba, extracts from Michelet, Sarcey's Le siege de Paris, Verne's stories.

FORMULATION IX.—One unit.

b. The Intermediate Requirement.

At the end of the intermediate course the pupil should be able to read at sight ordinary French prose or simple poetry, to translate into French a connected passage of English based on the text read, and to answer questions involving a more thorough knowledge of syntax than is expected in the elementary course.

The Work to be Done.—This should comprise the reading of from 400 to 600 pages of French of ordinary difficulty, a portion to be in the dramatic form; constant practise in giving French paraphrases, abstracts or reproductions from memory of selected portions of the matter read; the study of a grammar of moderate completeness; writing from dictation.

Suitable texts are: About's stories, Augier and Sandeau's Le Gendre de M. Poirier, Beranger's poems, Corneille's Le Cid and Horace, Coppee's poems, Daudet's La Belle-Nivernaise, La Brete's Mon oncle et mon cure, Madame de Sevigne's letters, Hugo's Hermani and La chute, Labiche's plays, Loti's Pecheur d' Islande, Mignet's historical writings, Moliere's L'avare and Le bourgeois gentilhomme, Racine's Athalie, Andromaque, and Esther, George Sand's plays and stories, Sandeau's Mademoiselle de la Seigliere, Scribe's plays, Thierry's Recits des temps merovingiens, Thiers's L'expedition de Bonaparte en Egypte, Vigny's La canne de jonc, Voltaire's historical writings.

Credit for Advanced French, in accordance with the recommendations of the Committee of Twelve, will be given when there is occasion for it.

GERMAN.

The definition of requirements in German are based upon the recommendations of the Committee of Twelve of the Modern Language Association.

FORMULATION X.—Two units.

a. The Elementary Requirement.

The Aim of the Instruction.—At the end of the elementary course in German the pupil should be able to read at sight, and to translate, if called upon, by way of proving his ability to read a passage of very easy dialogue or narrative prose, help being given upon unusual words and constructions, to put into German short English sentences taken from the language of everyday life or based upon the text given for translation, and to answer questions upon the rudiments of the grammar, as defined below.

The Work to be Done.—During the first year the work should comprise: (1) careful drill upon pronunciation; (2) the memorizing and frequent repetition of easy colloquial sentences; (3) drill upon the rudiments of grammar, that is, upon the inflection of the articles, of such nouns as belong to the language of everyday life, of adjectives, pronouns, weak verbs, and the more usual strong verbs; also upon the use of the more common prepositions, the simpler uses of the modal auxiliaries, and the elementary rules of syntax and word order; (4) abundant easy exercises designed not only to fix in mind the forms and principles of grammar, but also to cultivate readiness in the reproduction of natural forms of expression; (5) the reading of from 50 to 100 pages of graduated texts from a reader, with constant practice in translating into German easy variations upon sentences selected from the reading lesson (the teacher giving the English), and in the reproduction from parts of readers available for first year's class-work; good selections may be made from Müller und Wenckebach's Glück Auf; Kern's (Grimm's) German Stories Retold; Guerber's Märchen and Erzählungen; Seeligmann's Altes and Neues.

During the second year the work should comprise: (1) the reading of from 150 to 200 pages of literature in the form of easy stories and plays; (2) accompanying practise, as before, in the translation into German of easy variations upon the matter read, and also in the off-hand reproduction, sometimes orally and sometimes in writing, of the substance of short and easy selected passages; (3) continued drill upon the rudiments of the grammar, directed to the ends of enabling the pupil, first, to use his knowledge with facility in the formation of sentences, and, secondly, to state his knowledge correctly in the technical language of grammar.

Stories suitable for the elementary course can be selected from the following list: Andersen's Märchen und Bilderbuch ohne Bilder; Arnold's Fritz auf Ferien; Baumbach's Die Nonna and Der Schwiegersohn; Gerstacker's Germelshausen; Heyse's L'Arrabbiata, Das Mädchen von Treppi, and Anfang und Ende; Hillern's Höher als die Kirche; Jensen's Die braune Erica; Leander's Traumereien, and Kleine Geschichten, Seidel's Marchen; Stokl's Unter dem Christbaum; Storm's Immensee and Geschichten aus der Tonne; Zschokke's Der zerbrochene Krug.

Good plays adapted to the elementary course are much harder to find than good stories. Five-act plays are too long. They require more time than it is advisable to devote to any one text. Among shorter plays the best available are perhaps Benedix's Der Prozess, Der Weiberfeind, and Günstige Vorzeichen; Elz's Er ist nicht eifersuchtig; Wichert's An der Majorsecke; Wilhelmi's Einer muss heiraten. It is recommended, however, that not more than one of these plays be read. The narrative style should predominate. A good selection of reading matter for the second year would be Andersen's Märchen, or Bilderbuch, or Leander's Traumereien, to the extent of say forty pages. After that such a story as Das kalte Herz, or Der zerbrochene Krug; then Höher als die Kirche, or Immensee; next a good story by Heyse, Baumbach, or Seidel; lastly Der Prozess.

FORMULATION XI.—One unit.

b. The Intermediate Requirement.

The Aim of the Instruction.—At the end of the intermediate course the pupil should be able to read at sight German prose of ordinary difficulty, whether recent or classical; to put into German a connected passage of simple English, paraphrased from a given text in German; to answer any grammatical questions relating to usual forms and essential principles of the language, including syntax and word-formation, and to translate and explain (so far as explanation may be necessary) a passage of classical literature taken from some text previously studied.

The Work to be Done.—The work should comprise, in addition to the elementary course, the reading of 300 to 400 pages of moderately difficult prose and poetry, with constant practice in giving, sometimes orally and sometimes in writing, paraphrases, abstracts, or reproductions from memory of selected portions of the matter read; also grammatical drill upon the less usual strong verbs, the use of articles, cases, auxiliaries of all kinds, tenses and modes and likewise upon word-order and word-formation. A text-book, such as Harris', Wesselhoeft's, or Berhardt's, German Composition, should be used for this purpose.

The intermediate course is supposed to be the elementary course, plus one year's work at the rate of five recitations per week. Suitable reading matter for the third year can be selected from such works as the following: Ebner-Eschenbach's Die Freiherren von Gemperlein; Freytag's Die Journalisten und Bilder aus der deutschen Vergangenheit—for example, Karl der Grosse, Aus den Kreuzzügen, Doktor Luther, Aus dem Staat Friedrichs des Grossen; Fouque's Undine; Gerstäcker's Irrfahrten; Goethe's Hermann und Dorothea and Iphigenie; Heine's poems and Reisebilder; Hoffmann's Historische Erzählungen; Lessing's Minna von Barnhelm; Meyer's Gustav Adolfs Page; Moser's Der Bibliothekar; Riehl's Novellen—for example, Burg Neideck, Der Fluch der Schönheit, Der stumme Ratherr, Das Spielmankind; Rosegger's Waldheimat; Schiller's Der Neffe als Onkel, Der Geistersher, Wilhelm Tell, Die Jungfrau von Orleans, Das Lied von der Glocke, Balladen; Scheffel's Der Trompeter von Säkkingen; Uhland's poems; Wildenbruch's Das edle Blut.

Credit in Advanced German, in accordance with the recommendations of the Committee of Twelve, will be given when there is occasion for it.

SPANISH.

The definition of requirements in Spanish follow the recommendation of the College Entrance Examination Board.

FORMULATION XII.—Two units.

a. During the first year the work should comprise (1) careful drill in pronunciation; (2) the rudiments of grammar, including the conjugation of the regular and the more common irregular verbs, the inflection of nouns, adjectives and pronouns, and the elementary rules of syntax; (3) exercises containing illustrations of the principles of grammar; (4) the reading and accurate rendering into good English of from 100 to 175 duodecimo pages of graduated texts, with translation into Spanish of easy variations of the sentences read; (5) writing Spanish from dictation.

b. During the second year the work should comprise: (1) the reading of from 250 to 400 pages of modern prose from different authors; (2) practise in translating Spanish into English, and English variations of the text into Spanish; (3) continued study of the elements of grammar and syntax; (4) mastery of all but the rare irregular verb forms and of the simpler uses of the modes and tenses; (5) writing Spanish from dictation; (6) memorizing of easy short poems.

Suitable texts for the second year are: Valera's El pajaro verde; Alarcon's El final de Norma; Valdes's José; Galdos's Dona Perfecta, Marianela; Padre Isla's version of Gil Blas; Carrion and Aza's Zaragueta.

LATIN.

FORMULATION XIII.

In Latin the first two units are based upon the definitions proposed by the American Philological Association, and the third and fourth units upon the definitions proposed by the College Entrance Examination Board.

(*a*) Latin lessons, accompanied from an early stage by the reading of very simple selections. Easy reading: twenty to thirty pages of consecutive text.

In all written exercises the long vowels should be marked, and in all oral exercises pains should be taken to make the pronunciation conform to the quantities.

The student should be trained from the beginning to grasp the meaning of the Latin before translating, and then to render into idiomatic English; he should also be taught to read the Latin aloud with intelligent expression. One unit.

(*b*) Selections from Cæsar's Gallic War equivalent in amount to four books; selections from other prose writers, such as Nepos, may be taken as a substitute for an amount up to, but not exceeding, two books.

The equivalent of at least one period a week in prose composition based on Cæsar.

Reading aloud and translating, together with training in correct methods of apprehending the author's meaning, both prepared and unprepared passages being used as material. The memorizing of selected passages. One unit.

(*c*) Cicero: Any six orations from the following list, but preferably the first six mentioned:

The four orations against Catiline, Archias, the Manilian Law, Marcellus, Roscius, Milo, Sestius, Ligarius, the fourteenth Philippic.

Vergil: The first six books of the Aeneid.

The equivalent of at least one period a week in prose composition based on Cicero.

Note: In place of a part of Cicero an equivalent of Sallust's Catiline, and in place of a part of Vergil an equivalent of Ovid will be accepted. Two units.

HISTORY.

The definition of requirement in history is that recommended by the Committee of Seven of the American Historical Association.

FORMULATION XIV.

(*a*) Ancient history, with special reference to Greek and Roman history, and including also a short introductory study of the more ancient nations and the chief events of the early Middle Ages, down to the death of Charlemagne (814). One unit.

(*b*) Mediæval and modern European history, from the death of Charlemagne to the present time. One unit.

(*c*) English history. One unit.

(*d*) American history and civil government. One unit.

Each of the above topics is intended to represent one year of historical work wherein the study is given five times per week, or two years of historical work wherein the study is given three times per week.

This is contrary to the practise of many secondary schools which give only one-half of this time to English history and American history, although it is common in these schools to give one-half year to the study of civil government, which together with the half-year devoted to American history will make the required unit.

PHYSICAL GEOGRAPHY.

FORMULATION XV.—One Unit.

The following outline condensed from a report of the Committee on Definition of Physical Geography of the North Central Association of Colleges and Secondary Schools, includes only the essential facts and principles of physical geography, which must be studied in the class room and laboratory:

The Earth as a Globe.—Shape of earth: How proved; probable causes of. Size: How measured. Rotation: Day and night; longitude and time; latitude. Revolution: Rate; path; direction. Seasons and their causes. Magnetism: Compass; variation in. Map projection explained.

The Land.—Distribution. Graphic representation of topography. Changes in land areas and in land forms: Effects of (1) elevation and depression, of (2) disposition of sediments, (3) of shore erosion. Plains: Effect of climate and rock structure on topography of plains. Alluvial plains: their formation and importance. Relation of life to different forms of plains. Plateaus: Relations to plains and to mountains. Effect of climate, rock structure, etc., on topography of plateaus. Locations of the great plateaus. Life conditions on plateaus. Mountains: Classes. History. Effects of climate, rock structure, etc., on mountain topography. Life conditions in mountains. Volcanoes: Distribution. Phenomena of eruptions. History of a volcano. Influence of volcanoes on topography and life. Rivers: The work of rivers. The topography of surfaces shaped by river erosion at different stages of valley development. The great drainage basins of the United States. Lakes: The distribution of lakes, particularly in North America. The changes which they are undergoing.

Their effect on climate. Their relations to life in general. Glaciers: The nature of glacier ice. The distribution of glaciers. The conditions necessary for glaciers. The work of glaciers.

The Atmosphere.—Composition and offices of atmosphere. Instruments used in study of atmosphere. Temperature: Source of atmospheric heat, and variations of atmospheric temperatures. Isothermal charts. Pressure: Measurement of pressure. Determination of altitudes by atmospheric pressure. Relation to temperature. Study of isobars. Circulation of atmosphere: Winds; their causes; their classes; and their effects. Moisture: Sources. Conditions for precipitation. Forms of precipitation; rain and snow; dew and frost. Relation of precipitation to life. Storms: Relation of storms to general weather conditions. Study and construction of weather maps. Relation of weather to climate. Relation of climate and weather to life and to human industries.

The Ocean.—Form, divisions and general characteristics of the ocean, and of ocean basins. Depth, density and temperature of ocean waters. Characteristics of ocean floor; topography, material, etc. The life of the oceans. Movement of ocean waters: Waves; cause and effect. Currents; effects of currents on climate, life, etc. Tides: character of motion; causes of tides; variation of tides, and their causes; bores; effect of tides on navigation, harbors, etc. Work of ocean; Erosion and deposition. Shore lines: Influence of harbors and coast lines.

Summary.—The outline given can but enumerate the larger topics to be covered, and in a way suggest the point of view desired. Each topic should be treated so as to show its causal relations to other topics. So far as possible, the effects of earth features on life (especially human life) conditions should be emphasized.

Throughout the work an effort should be made to develop the student's ability to use the data presented. The acquisition of the facts presented in the text-books is in itself of relatively little value. The student should be taught to apply, out-of-doors and in the laboratory, the principles developed in the class room. When he can do this, and when he can utilize and combine the data presented in the books in new ways and to new ends, one of the chief aims of the study will have been accomplished.

The candidate's preparation should include:

(*a*) The study of one of the leading secondary text-books in physical geography, for the sake of essential principles, and of well-selected facts illustrating those principles.

(*b*) Individual laboratory work should occupy from one fourth to one half of the time of the student in the class-room. Field trips should take the place of some of the laboratory work in autumn and spring. The results of laboratory work should be carefully recorded in writing, and in many cases should be made the basis of class-room discussion. Similarly the field work should be made the basis of written reports or of subsequent class-room discussion, or both. In general, the laboratory and the field should be made to afford illustrations of as many principles and phenomena as possible.

MANUAL TRAINING.

Shop Work and Drawing.

Much difficulty has been experienced in formulating definitions of requirements of subjects in the mechanic arts. In fact, there is practically no general unanimity of opinion as to definitions of these subjects. The time element enters very largely into these definitions since practise must necessarily constitute a valuable part of the work and the measure of work accomplished is largely determined by the time spent on the subject.

What is meant by manual training has been discussed by educators for a number of years. Your Committee on Entrance Requirements for Engineering Colleges formerly failed to agree as to what should be included under manual training or how this subject should be defined.

The subject was under discussion for a year or two before the Eastern Manual Training Association and the decision arrived at by that body was that the time devoted to a given subject be accepted as a unit of manual training work, but what this work should consist of or how it should be administered was not stated.

More, recently, 1907 and 1908, the Committee of the North Central Association of Colleges and Secondary Schools (C. M. Woodward past-President of this Society, Chairman) considered this question, and reported essentially as follows:

"We have, therefore, defined shop-work and drawing, as it exists, or should exist, in a well-organized and fully equipped city manual training high school. If for any reason a high school undertakes less than the full amount we specify, we recommend that it take up subjects in the order we name them and cover the ground thoroughly, as far as it goes. A high school is not, and cannot be, a high-grade technical school, and nothing is gained by skipping the broad foundations of manual and graphic culture and attempting prematurely to do engineering work."

FORMULATION XVI.

The minimum time given per year in order to count as a unit should not be less than the equivalent of 240 hours of 60 minutes each. No superior limit is given, but additional hours should not receive additional credit.

Shopwork.

Every exercise which is involved in what follows should be planned and executed to illustrate an important mechanical principle or process, or a combination of such principles and processes.

The exposition of a tool and the demonstration of a process should be before the entire section of pupils conveniently seated so as to see all that the teacher does, and hear all that he says.

The shop-period of first-year boys ought not to exceed 100 minutes in length; but third and fourth year pupils can profitably have longer, but less frequent shop-periods; however, those periods should never exceed 180 minutes.

Pupils should never be left to find out for themselves the proper ways of using a tool. The correct ways should be clearly and fully shown and explained. The use of a wrong tool, and the adoption of an illogical or unscientific procedure should at once be checked, and the error should be plainly pointed out.

Bench Work (One unit).

(*a*) Fundamental tool processes: Measuring, squaring, gauging, sawing, boring, chiseling; rules for planing.

(*b*) Constructions involving groove joints and halving; laying out and cutting joints; use of nails, screws and glue; carving and finishing.

(*c*) Making a glue joint; planing joints, gluing, clamping, surfacing, sandpapering.

(*d*) Construction by means of mortise-and-tenon joint; laying out duplicate parts, cutting mortise, sawing tenon, gluing and clamping, scraping, finishing.

(*e*) Construction involving the miter joint; planing parallel edges and sides in the construction of a miter box; rebating, laying out and cutting a brace.

(*f*) Dovetailing: laying out and cutting dovetails, planing corners, inlaying.

(*g*) Construction involving the use of the panel: plowing, fitting, gluing, clamping, putting on hinges, finishing.

Wood-Turning and Elementary Metal-Working (One unit).

1. Wood-turning. Use of different kinds of wood. Care of lathe.

(*a*) Turning spindle, cylinder, taper, convex curve, concave curve, compound curve; turning to given dimensions, finishing and polishing in the lathe.

(*b*) Faceplate turning.

(*c*) Chuck turning; built-up stock, fitting.

2. Metalworking. Working in a variety of metals, including cast-iron, steel, brass, tin, zinc, and copper.

(*a*) Chipping and filing; chipping with cold chisel and hammer; filing, testing, tool dressing.

(*b*) Making small tools. Drilling, filing, fitting, riveting, finishing.

(*c*) Construction in sheet metal; pattern cutting, bending, folding, wiring, soldering.

(*d*) Copper work: sawing, beating, hard soldering, repoussé, annealing, coloring with heat and chemicals, etching.

(*e*) Turning: Hand-tool turning, filing in lathe, polishing in lathe, thread cutting with tap and die, hardening, tempering, annealing.

(*f*) Spinning: cutting templet, turning form in wood to fit templet, spinning zinc or Britannia metal and copper, polishing, lacquering.

Pattern Making, Molding and Forging (One unit).

The theory and use of patterns, how built, how divided and why; pattern-making, bench-molding of simple and complex patterns; theory and use of cores, construction of cores and core-prints; casting with lead and alloys.

Construction and management of the forge—fundamental processes; drawing, up-setting, bending, punching, splitting, welding, hardening; shaping steel under the hammer; tempering of different grades; the construction of chains, hooks and forge tools, and wrought-iron articles from original or selected designs; finally the manufacture of a set of standard steel lathe tools. The design and actual construction of a piece of ornamental wrought-iron or steel work.

Bench and Machine Metal Fitting (One unit).

Theory of metal-turning, centering; forms of cutting tools and tool-grinding; turning cast-iron, wrought-iron, steel, and brass; use of oil, relation of speed to heat developed; use of taps and dies; screw cutting, chuck-work, mandril and face-plate work; drilling, slotting, planing, gear-cutting, and special work on the milling machine. Having mastered the elements, each student should combine more or less of such elements in a construction, made in accordance with original or selected drawings.

MECHANICAL DRAWING.

FORMULATION XVII.—Two units.

1. (*a*) Straight lines; use of T-square, triangles, pencil, ruling pen, dividers, and scale. Conventional lines. Freehand working sketches.

(*b*) Circles. Use of compasses, center lines, crosshatching.

(*c*) Tangents. Location of centers and points of tangency.

(*d*) Planes of projection; elementary principles of projection; revolution of the planes of projection. Projections of simple geometric figures.

(*e*) Revolution of objects. "Views" of objects in simple and inclined positions.

(*f*) Developments: prism, cylinder, pyramid, cone.

(*g*) Intersections. Axes in the same plane, axes in different planes.

(*h*) Isometric and cabinet drawing.

(*i*) Freehand and mechanical lettering; placing, form slant, spacing, stroke.

(*j*) Working drawings; furniture.

(*k*) Working drawings; machine parts.

(*l*) Building plans; floor plans, elevations.

2. (*a*) Mechanical perspective.

(*b*) Freehand drawing in perspective.

(*c*) Construction of conic sections and helix.

(*d*) Line shading.

(*e*) Wash drawing.

(*f*) Designing for metal work.

(*g*) Either machine or architectural drawing.

The Committee on Manual Training of the North Central Association of Colleges and Secondary Schools has also presented (1909) the following definitions of requirements in Free-hand drawing and applied art:

FREE-HAND DRAWING AND APPLIED ART.

FORMULATION XVIII.—Two units.

Approximately one-third the time should be given to representative drawing and two-thirds to decorative composition, constructive and decorative design, construction and applied design.

(*a*) Pictorial. Plant study (flowers, sprays of leaves, seed, pods, etc.). Object study; landscape, roof studies, buildings, etc.; pose drawing; composition.

(*b*) Decorative Composition. Plant forms, object study, landscape, pose.

(*c*) Decorative Design. Plant analysis (for the purpose of design). Conventionalized plant forms; decorative units, borders, surfaces, corners, rosettes, posters, book-covers, etc.; stencils, wood-block printing; historic ornament; arrangement of straight lines, and of straight and curved lines; geometric design; lettering, illuminating; schemes for interior decoration.

(*d*) Constructive Design. Designs for pottery, leather, metal, book-binding, furniture, cardboard construction, textiles, etc.

(*e*) Crafts. Pottery, leather, metal, book-binding, furniture. (Choice of one or more of the above crafts.)

(*f*) Applied Design. Design applied to the crafts and to cardboard, textiles, etc.

(*g*) Illustration.

(*h*) Talks on history of industry and art, on civic planning, domestic architecture and decoration.

(*i*) Instrumental drawing to be given as needed to meet the requirements of practical designing and construction.

Note. Mediums used—pencil, charcoal, water color, crayons, brush and ink, and a combination of the pure mediums.

(Signed)

J. P. Jackson,
C. D. Marx,
F. O. Marvin,
F. W. McNair,
J. C. Nagle,
J. J. Flather,
Chairman.

Discussion.

Professor Emory: I desire to make a few remarks regarding the subject of higher algebra. This society has been in existence about twenty years, and of all the matters taken up in that time few have been of more importance than the subject of this report. I agree with the Committee in their action in omitting about one-third of what has been considered higher algebra. It seems absurd to attempt to teach a student the theory of equations at the time and in the place it is now often taught under higher algebra. Few students really understand it. We should not put into the entrance requirements subjects, which were discovered by men of great and mature minds after years of study; subjects which were discovered by mathematically-trained men who had the advantages of the highest mathematics. If, as I understand it, the Committee intends to include only those parts of higher mathematics for which the students can see the direct reason and eliminate those parts which really depend upon later education, we have made a step forward. It will be a great help to teachers of mathematics if we put the requirements so concisely that they will be perfectly clear. In my opinion it would be better to put higher algebra in the college course with calculus and differential equations. Then the student will see what it is all about and he will get some benefit from it.

Professor Flather: In this connection allow me to emphasize one statement in our report. "It has become more and more evident that a change in the arrangement of the subject matter involved is desirable." The idea is to have something that we can agree upon that will give the student a conception of what this algebraic work is, even if it does involve the introduction of geometry and trigonometrical work along with the teaching of algebra.

Mr. Kent: I agree most cordially with what has been said with regard to higher algebra. I was asked some years ago by an association of teachers of mathematics what algebra is required for college. I said, "I would divide the algebra book into three parts, and the first third of it I would ask the student to pass with a grade of 100 per cent.; that is, he could be perfect; perfect through higher quadratic equations. On the second third he should pass an examination and get 50 per cent.; upon the third part I would not examine him at all; leave that part of the work for future reference." I agree perfectly with Professor Emory that the use of the last part of higher algebra is merely the cramming for examinations and leads to that result.

The list of prescribed subjects given by the Committee making a total of seven or eight units, leaving seven or six additional units to be elective, in order to make a total of fourteen, seems to the writer defective in that it does not insure to the student entering college such a sufficiently broad training in different branches of desirable knowledge. Some years ago in considering this question I made a list of general subjects in which every high school graduate should receive instruction in order that he be equipped with the foundations, at least, of a broad and liberal culture. These subjects are: English, mathematics, history, drawing, natural science, physical science (physics, chemistry), foreign language.

Not one of these subjects, except possibly the last, can be omitted from the curriculum of a broadly educated man. If a student neglects English he is illiterate; if he does not study mathematics, part of his brain power is not developed; if he omits history he is not an intelligent citizen; if he knows nothing of drawing he will not know how to appreciate art or how to express his ideas in graphical form; if he does not study natural science the world of nature is a closed book to him; if he is not instructed in the elements of physics or chemistry he is ignorant of the foundations of modern industrial processes. He may be able to do without a foreign language, but the mental training and discipline, together with the improved knowledge of one's own language that the study of a foreign language gives, make the study a desirable, if not an essential one. Each one of the several studies above named is essential, and essentially different from any other, not only in the kind of information it gives, but also in the method required to teach it and in the brain faculty needed for and developed by its acquirement. The teacher of each one may dilate upon any of its especial merits as a branch of education, but the fact is that they are almost equally desirable, and all needed in order to make a man of broad culture.

I suggest the following division of the fourteen units among the seven required subjects: English (2), mathematics (3), history (2), drawing (1), natural science (1), physics or chemistry (1), foreign language (2).—Total (12). This leaves two units to be elective, which may be either additional units in any of the above subjects, or shopwork (1), or manual training (1).

The scheme of the Committee prescribes only seven or eight units, viz.: English (3), mathematics (3), physics or chemistry (1), or foreign language (2). In either case only three of the seven above named subjects are prescribed. The seven or six electives might be made up in such a way as to leave out drawing and natural science, both of which are essential to a broadly educated man.

We have been talking lately about the desirability of having broad, liberal culture. We should consider what is the meaning of broad culture. Does it mean anything but instruction, information, education on a wide line of subjects? If we prescribe but three subjects out of seven that ought to be taught, leaving the rest as elective, the student may have a narrow culture. By a poor selection of electives, with all of his fourteen units he may omit two things which are essential to an educated man, drawing and natural science, biology, botany, zoölogy. Some of those subjects ought to be brought before every high school student. So I think that the Committee should broaden out the requirements and insist on something in all of the seven subjects mentioned, for not one of these may be neglected from a curriculum of a broadly educated man.

Professor J. E. Boyd: In my opinion this report has more merit for the things it leaves out than for what it contains. I judge elementary text-books by what they do not contain. Some elementary text-books in physics discuss *X*-rays and polarized light, etc. A zealous teacher wants to put this into the high school curriculum and as a result some very wishy-washy college science is taught. Similarly with economics. We all know that the high school student has not enough maturity to appreciate this sort of teaching, and I am glad to see such subjects omitted from our list. I believe in the study of history, especially American history. It is said that any educated man wants to know what has happened. A great many of those crazy notions that we see now in economics and politics have been tried out, sometimes centuries ago, and if we had read a little history we would have known that they had been shown to be failures. Therefore any man, engineer or otherwise, who makes any claim to intelligence should have some history and the best time for him to get it is when he is young, while his memory is good. There is an excellent reason for requiring at least four units of foreign language, and that is to enable us to get better English. For the English alone, I would rather have a student who had two units of English and four units of Latin, German, or French under a good teacher, than one with six units of English without the foreign language.

Dean J. P. Jackson: Regarding the matter of adding to the number of subjects which are specifically and positively required, I am sure, assuming that we could by our actions bind every institution teaching engineering in the United States, that the addition of further specific subjects to the entrance requirements would result in a powerful influence on the work of the high schools. That might be well, and then it might not—the question is debatable. We have had, at Pennsylvania State College, several conferences of high school principals from over the state. In these conferences the bitterest and the most earnest objection made to the average college is the fact that students are permitted to enter only under such rigorous conditions as have been outlined in part of this discussion. I am inclined to agree with the high school men that it is not well for students to be permitted to enter college only under such rigorous conditions as suggested, or as now commonly exist. The high schools, which are teaching from ten to fifteen young men for each one who goes to the college, must have as their primary object the preparation of the larger number of these young men directly for life. If we intend to be fair and helpful to this great number of students, we must be careful to make our demands such that they will enable the preparatory schools to enter into college, with as little restriction as possible, the small number of boys that are able to pursue advanced study. I believe that the Committee had these ideas in mind when making the recommendations which it has submitted to you.

President Talbot: The point which Professor Jackson makes is a very good one, one quite generally overlooked in college administration.

Professor Williston: There is at the present time a movement almost nation-wide respecting the adoption of a more liberal policy towards the high school on the part of colleges, in just the direction that Professor Jackson has pointed out. The two most conspicuous examples of this are the action of Chicago University, which has adopted a plan almost identical with the one recommended by the Committee, except that ten units are prescribed and five are elective. This gives the high schools the freedom to do the very thing to which Professor Jackson has called attention, and at the same time insists on sufficient concentration on what are regarded as the absolutely essential things in English, mathematics and science. The Harvard plan as recently announced, is almost identical with the Chicago plan although less definitely stated. The Committee of the National Educational Association is working on this, as several other committees throughout the country are doing. It seems to me that there is an unusual opportunity at the present time for the Society to do a piece of constructive work in helping towards the realization of a more nearly common entrance requirement and a type of requirement which will make it possible for high schools to do a very much better grade of work than they have done in the past. This movement has been in a certain sense a reform on the part of the high school, a demand for freedom to do justice to their students and to send out boys not crammed for certain examinations but equipped with ability and mental poise.

Professor Magruder: I wish to draw attention to a recent issue of *Science* in which a gentleman speaking for Chicago University called attention to the fact that a student must present three units in English on a minimum of fifteen units, five in modern language, history and science; and he particularly calls attention to the fact that they need not have worked in three branches. That permits the high school boy to be entered who has had three units of English and twelve units of ancient and modern language, has never studied algebra, geometry or trigonometry and has never done any work in science and has never studied any mathematics except what he may have gotten from the grammar schools. That is swinging the pendulum too far.

Professor Hugh Miller: At the Clarkson School of Technology we admit chiefly on regents' certificates of the N. Y. State Education Department but I have figured out our requirements of seventy-two regents' counts on the basis of Carnegie units. We require thirteen regents' counts in English, or two and one half Carnegie units; in the science group, the equivalent of two Carnegie counts; history and social science group, two; algebra (elementary, intermediate and advanced), two; plane geometry, one; solid geometry, one-half; total required, ten. Then electives, four and a half, making a total of fourteen and a half counts required for entrance.

I will simply note for example that in the science group, physics counts five regents' counts, or one Carnegie unit; chemistry also would be one Carnegie unit; making a total of two. That is to say, a student could offer both physics and chemistry and get the required counts. Otherwise he could present either of those and take any two of the following three, physiology, botany or zoölogy, each of which is one half a Carnegie unit, or he could take biology, advanced botany or zoölogy or physical geography, each of which is equivalent to one Carnegie unit. That is to say, he could present either physics or chemistry, and a combination of both zoölogy or physiology, or any two of the three subjects equivalent to one half a unit, or any one of those equivalent to a full unit. Moreover, he could enter without either physics or chemistry, provided he had the necessary two units in the science group, but this rarely happens.

Among the electives are the modern languages and a large number of miscellaneous subjects; in fact there are fifty or more subjects in the list of electives, including all those on the board and a great many others.

Professor Emory: I would like to ask a question of Professor Williston, as a representative of those who desire to expand the high school work. How do those in favor of it reconcile the fact that they quote President Elliott of Harvard University in demanding a greater scope in elementary education, while President Elliott, who inaugurated the elective system at Harvard, recently said it is carried too far and will have to be changed slightly? How can those two positions be reconciled?

Professor Williston: The elective system when it was introduced into Harvard resulted in a lack of concentration on single subjects. In copying the elective system of Harvard the high schools have put in a little of each of a great many things, and the colleges, taking what the high schools have furnished, have required a little of a great many subjects. The plan for which Harvard has been working and for which Dr. Elliott has been speaking is to permit the student to elect the type of study for which he believes himself naturally fitted and in which his greatest interest lies. But in any selected course he is expected to devote time and attention to his work and to do it thoroughly. In other words, the group system has been advocated by Harvard and it is in this direction that the high schools desire the privilege of selection, for example in the case of the student who wants mathematical training. So also for the one who wants natural science and the one who wants language. Each should have time enough for his special group of subjects. Now if the high schools in different communities, meeting the respective needs of those communities, adopt suitable courses, these schools must demand that the colleges be more flexible, giving a wider range for election, and giving a smaller list of absolutely prescribed subjects, prescribing perhaps two thirds and giving freedom for the remainder.

Professor Flather: In concluding the discussion I would emphasize the desire of the committee that every member of this society see to it that the recommendations be adopted in so far as they can have them adopted in their respective communities. Now we have been in correspondence with all of those societies concerned with entrance requirements, and our recommendations are largely those which have already been agreed upon by the national societies. The specifications are in existence and are accepted largely by the various examination boards. What we want is some degree of uniformity. We must be moderate in our prescribed requirements and we must ask for something that will fit our students for engineering work and at the same time furnish a certain amount of culture study; then let the high schools exercise a fair degree of freedom in the choice of the remaining subjects. This does not mean that the pupils in the high schools are going to browse around. The schools in general are well organized but they do not always have teachers for all the different branches desired. Sometimes it is the sciences, in other cases it may be the languages that must be reduced. In such cases it may be that there is a good teacher of history. Now a student coming from such a high school which gives a good course in history can elect four units in the history group.

Other schools may not have a good teacher in history, but may have excellent courses in physics and chemistry. A certain freedom of choice should therefore be allowed to the high schools in order that they may adapt their curricula to their particular conditions. Since we should not be too rigid in our requirements, let us agree on a group of seven or eight subjects, as indicated here, and then let the high schools fill in the other requirements from a list of electives which, however, should not be too comprehensive. With such an accepted list, provided the subjects be properly taught, a boy can prepare in any high or secondary school for any college. This is what we have been aiming at for years, namely, that it shall be unnecessary to choose any particular college and prepare for it four years before matriculation.

LOGARITHMIC DIAGRAMS AND THEIR USE IN LABORATORY WORK.

BY MR. H. A. GEHRING,

Department of the New York State Engineer, Albany, N. Y.

For several years I have had occasion to compute the flow of rivers from records kept at various dams. These records include the observed gage readings and the different lengths and heights of flashboards on both dam and spillway. At the time when I first took up this work, the method in use was to make out rating tables for all those conditions of flashboards which seemed to obtain most of the time, but there were also many conditions which obtained for short periods of time for which no tables were prepared. The discharge for these conditions was computed by formulæ. Obviously, where the crest conditions changed frequently, it was a long and tedious task to compute the discharge.

My attention was called to several articles in the *Engineering News* in which logarithmic diagrams were presented and it was suggested to me that I study into the principles on which such diagrams are constructed with a view to applying them to computations of the kind above given. Of the diagrams accordingly constructed one in particular has proved exceedingly practical and time-saving. This diagram gives the discharge over any length of crest for any head and for any coefficient.

During three years, while an instructor in hydraulics and mechanics at Cornell University, I had considerable experience in laboratory work. This experience has led me to conclude that logarithmic diagrams can be used to good advantage in the laboratory, and for the purpose of presenting this subject before this society, I have prepared the following paper which is divided into two parts.

PART 1. *Principles of Logarithmic Diagrams and the development of equations capable of being represented diagrammatically.*

This part appears in full in my article in the *Engineering Record* of January 15, 1910. It was originally intended to reprint it at this time, but upon further consideration it seemed inadvisable to do so because it is entirely of a theoretical nature, and because the above periodical is accessible to all who desire to investigate farther.

PART 2. *Suggestions regarding laboratory work with an illustration of the applicability of logarithmic diagrams.*

In the first place I believe firmly in the graphical representation of equations. Many data are conveniently put into tabular form, but where the data acquired can be stated in the form of an equation, their representation graphically is not only of practical accuracy and convenience, but it also stimulates in the student the excellent habit of graphical representation wherever possible.

The best method of presenting the subject of logarithmic diagrams to the student is in connection with a laboratory course. I am inclined to believe that too large a percentage of the time assigned to a laboratory course is spent in the computing room, and the adoption of means to facilitate the computations is highly desirable. Also as much of the computing as possible should be done in the laboratory itself and during the course of the experiment, leaving some period assigned to the computing room to be used in writing up a report on the work with a discussion of the results obtained.

I desire to lay great stress on the advisability of carrying on a certain amount of the computations abreast of the experiment. Too often in the computing room results are obtained which are obviously wrong. Much time is then wasted by the student in attempts to recall the circumstances of the experiment to see what might have caused such an error, but he cannot find the cause. It might have been an error in reading a gage, or the incorrect recording of the stop-watch, or an unobserved leakage of a valve, or as is frequently the case, the man recording the data might have failed to hear and record accurately the information given to him. If all of the observed data can be utilized immediately to obtain the computed quantities finally desired, any error or discrepancy can be detected at the critical moment and rectified while the apparatus is still in position. Speaking from my own experience, I can state that the whole class is reasonably interested in the laboratory work while becoming familiar with the apparartus, and until a point is reached where each man has had an opportunity to read the different gages and to obtain the different observed quantities. Generally speaking, from that point on, the remainder of the work is done more or less mechanically and with a lagging interest which injects into the students a carelessness often evidenced by erroneous observations. Right here lies one of the strongest features of the system of plotting and computing the data as quickly as observed and recorded, as by so doing, carelessness is immediately detected and the guilty student apprehended. Hence this method yields both greater efficiency and greater interest, and indeed the latter alone need only be mentioned, for greater interest must of necessity imply a higher efficiency.

By way of illustration I will assume a class in experimental hydraulics and an experiment to determine the law of friction in a 4-inch pipe. I will also assume that the pipe is laid horizontally so that the loss of head read on the differential pressure gage may be attributed entirely to friction. For small velocities the water will flow into a pan placed on a scale and will be weighed, while for larger velocities a calibrated tank will be used to determine the total flow during the run. The quantities observed are either the total weight of water in pounds, W, or the total volume in cubic feet, Q_T, the length of the run in seconds, T, and the readings of both legs of the differential pressure gage. This actual observed loss of head I will designate by H_L and the loss in feet per thousand feet by H_f.

As soon as any run is completed and the observed data recorded by the recorder, the latter refers to the diagram shown in figure 1 and with a thread stretched taut obtains the velocity indicated by the observed total flow and the length of the run. This diagram should have been constructed by each student previous to the experiment and during an assigned computing period after a lecture by the instructor in charge. While a diagram can be made applicable to more than one diameter of pipe, it is advisable to require each student to construct a diagram for each size of pipe to be tested. This both gives him a better drill in and understanding of the diagrams, and also allows the diagram for each pipe to be drawn to a larger scale than would be convenient where too large a range of values is attempted on one diagram. The equations for this diagram are obtained as follows:

When the volume of water in cubic feet is observed and the diameter of the pipe is in inches,

$$Q_T = \tfrac{1}{144} \cdot \tfrac{1}{4} \pi d^2 TV,$$

which for $d = 4''$ becomes

$$Q_T = 0.087\ VT.$$

When the water is weighed, assuming the weight per cubic foot as 62.5 pounds, the resulting equation becomes

$$W = 5.45\ VT.$$

Ordinary logarithmic cross section paper should also be on hand in the laboratory, and as soon as the mean velocity is obtained as above described, it is plotted on this paper as an abscissa with the loss of head in feet per one thousand feet, H^F, as ordinate, computed from the observed loss, H_L. After a few points are thus plotted and the slope of the line well defined, any subsequent point which falls appreciably off the line immediately indicates an error somewhere. In this way some fault with the apparatus or gages is often detected which otherwise might have been overlooked and so have affected a series of runs, and this fact would not have become known until perhaps a week later when the class met for computations. When the experimental work has been completed, not only has every student had an oportunity of learning the details of the experiment, but all the results obtained have already been plotted.

If no further experiments on other pipes are contemplated, the next assigned laboratory period should be devoted to computing. All the data obtained during the actual experiment should be in the possession of the instructor in charge between meetings of the class. In this interval he can examine the data at his leisure, and having weighed the plotted points, draw in the final line. The first part of the computing period should be devoted to a review of the experiment by the instructor and to clearing up all points of doubt. Each student should then be asked to plot the points on a sheet of ordinary logarithmic cross section paper and to reproduce the line as established by the instructor, obtaining its equation in the form,

$$H_f = mV^n.$$

When this has been done, a brief report should be written by each student and this submitted with his own plotting. The work done in the computing room ought not to require more than one hour of time.

I now wish to arrive *approximately* at the percentage of time saved through the adoption of the idea of plotting the data obtained during the course of the experiment itself and through the facilities of the logarithmic diagram used. In doing this, I will not count in the time devoted to the construction of the diagrams, as diagram No. 1 can be used for subsequent experiments and hence this time cannot properly be charged against the particular experiment in question.

Assuming three-hour laboratory sessions, there are three hours given to the experimental work and the collecting of data. When these data must be computed in the computing room at the next meeting of the class, my experience leads me to conclude that not less than three hours will be required

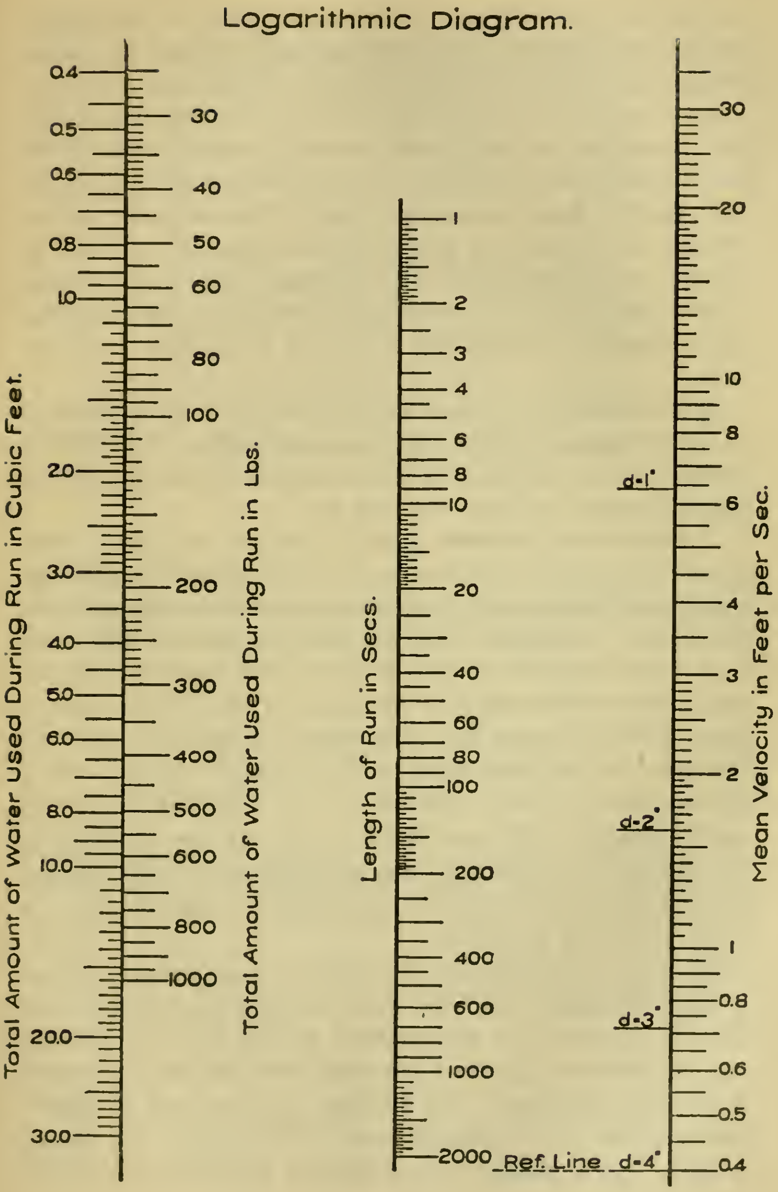
Logarithmic Diagram.
Total Amount of Water Used During Run in Cubic Feet.
0.4
0.5
0.6
0.8
1.0
2.0
3.0
4.0
5.0
6.0
8.0
10.0
20.0
30.0
Total Amount of Water Used During Run in Lbs.
30
40
50
60
80
100
200
300
400
500
600
800
1000
Length of Run in Secs.
1
2
3
4
6
8
10
20
40
60
80
100
200
400
600
1000
2000
Ref. Line
Mean Velocity in Feet per Sec.
30
20
10
8
6
4
3
2
1
0.8
0.6
0.5
0.4
d-1"
d-2"
d-3"
d-4"

FIG. 1.

for this work when done by the use of tables and slide rule. I think that this is a very fair estimate, because an undue proportion of time is usually spent on points which are obviously wrong in an attempt to recall the circumstances of the experiment and so explain the wide discrepancies which it is not expedient to ignore. At the following meeting of the class, another hour devoted to a talk by the instructor and to writing up a report on the experiment may be sufficient to dispose of the entire subject; and hence I will allow a total of seven hours to the experiment and report and the obtaining of the equation representing the law of friction in the 4-inch pipe.

By the method of computing and plotting in the laboratory as above explained a total of 4 hours will suffice. Thus it will be noted that a saving of 3 hours has been effected, and this means a saving of 43 per cent. in time.

If experiments on other sizes of pipe are to follow, these should be performed at successive periods and the data observed and computed in the laboratory should be left with the instructor. Assuming that, in all, three sizes of pipe have been experimented on and three sets of plottings obtained, an inspection of the diagram, shown in Fig. 2, will make it apparent that if each line were drawn by itself without any reference' to the other lines, each line might justly have a different slope n and coefficient m. To obtain uniformity of results which I think is advisable in an experiment like this, the instructor should give due consideration to the plotted data and by trial obtain one line which will answer for each of the three sets of points.

At the next meeting of the class for computations, where a series of pipes have been experimented on, I do not consider it necessary for each student to plot all the points for the experiments. If the laboratory work has been arranged to the best advantage, each student will have had an opportunity to take notes and plot some of the points. He should, however, equip himself with a sheet or logarithmic cross sec-

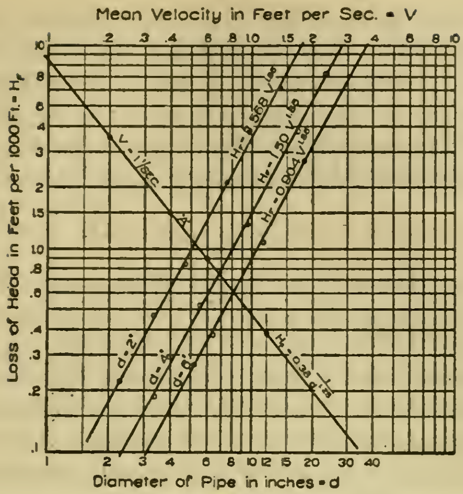

FIG. 2.

tion paper with four panels as shown in diagram No. 2 and on it reproduce the three lines as determined by the instructor. The resulting equations are as follows:

For the 2″ pipe, $H_F = 3.5684\ V^{1.86}$ (A)

For the 6″ pipe, $H_F = 0.9038\ V^{1.86}$ (C)

For the 4″ pipe, $H_F = 1.5003\ V^{1.86}$ (B)

Here the student's attention should be called to the fact that the exponent of V is the same for any size of pipe, and the question should be propounded "What will the coefficient reduce to when the diameter of the pipe is 1 foot or 12 inches?" To ascertain this, the student should note that for $V = 1$ foot per second,

$H_F = 3.5684$ when $d = 2''$,

also

$H_F = 0.9038$ when $d = 6''$.

and

$H_F = 1.5003$ when $d = 4''$,

Hence plotting these values of H_F as ordinates with the corresponding values of d as abscissæ, there results the line marked A. To determine its equation, it must be extended until it intersects the vertical line for $d=12''$, when the value of H_F becomes 0.38. The slope of the line is negative since H_F decreases as d increases, and its value is 1.25. Hence the equation of this line becomes $H_F=0.38\frac{1}{d^{1.25}}$.

Combining this with the results of equation (A), (B) and (C) there is developed the general equation $H_F=0.38\frac{V^{1.86}}{d^{1.25}}$ which holds good for all sizes of pipe and for all velocities.

This equation is of standard form and is frequently seen in engineering literature, yet few students know how it is derived. I have no doubt but that in most laboratory courses in Experimental Hydraulics, not enough time is available for the course to permit of devoting to the subject of friction in pipes the time required to develop this equation. If, however, an appreciable saving of time can be effected by the adoption of means to facilitate the computation of data, it may become possible to develop this general equation, and it is surely advisable to do so.

Now to arrive at an approximate idea of the time saved through plotting the results during the course of the experiment itself and through the facilities of logarithmic diagrams, I will make the assumption that the equipment of the laboratory is such as to require a full three hour period for the experimental work on each of three pipes to be tested. If, then, 9 hours are devoted to obtaining observed data, so much data will be collected that say 6 hours will be required to make the computations in the computing room. Allowing 1 hour for a report on the experiment, there results a total of 16 hours devoted to the work. By carrying on the computations and the plotting abreast of the experiment, these 6 hours of computing can be saved; hence a total of 10 hours only will be necessary for the work; or a saving of 38 per cent. in time.

Too much weight must not be given to the actual percentages of time saved which I have deduced. The significance of these figures lies not in the fact that they show just what time can actually be saved by the methods above described, but in the fact that they do demonstrate that a sufficient saving of time can be effected to warrant the consideration of our engineering faculties.

Discussion.

Professor Geo. Jacob Davis, Jr. (by letter): Laboratory courses are planned with various purposes in view, depending upon the nature of the subject to be taught, the time available, the adequacy of the equipment, the ability and experience of the instructors and the previous preparation of the students. A course may be planned to give merely familiarity with certain instruments or machines, and a knowledge of the methods of their calibration, adjustment and use, it may be intended to teach the general principles and methods of experimental work, or it may be planned to illustrate and emphasize the theoretical relations involved in the subject. In only exceptional cases, where a large amount of time is available for the purpose, can an attempt be made to develop skill in experimental work.

In those elementary courses dealing primarily with apparatus, there is usually little time for or need of the use of logarithmic diagrams, such as those described by the author. Their use as tools for expediting and facilitating routine computations is offset by the time required for explaining their construction and use, and by the loss of practice in calculating, which is badly needed by most engineering students. When the aim of the course is to develop in the student the ability, not only to perform experiments himself, but to analyze and interpret the experimental results of others, then the value of such work as is described by the author becomes apparent. Constantly, throughout the career of the engineer, he is called upon to select and use experimental coefficients, many of which are inconsistent or based on inadequate or faulty experiments. It is, therefore, of considerable importance that the engineering graduate should be acquainted with some of the methods of analyzing experimental results, so that he may be able to select for his use those that seem to be most reliable. One of the most convenient and valuable means of comparing the results of experiments is by plotting them to logarithmic scale, as illustrated by the author's Fig. 2.

For several years it has been the writer's custom to devote one lecture to a discussion of the various methods of comparing experimental results and of detecting instrumental and observational errors, and another lecture to an explanation of the method of determining the equation of a line averaging experimental values which fall on one of the simpler mathematical curves. Following this the students are required to determine the equation of a line satisfying certain experimental values which are given to them from some reliable experimental data. The purpose of these lectures and the problem has been to impress the student with the fact that it is important that experimental coefficients be compared and verified, and to acquaint him with a few of the simpler methods of accomplishing these ends. It has been deemed inexpedient to devote a larger amount of time to work of this sort in a short course in hydraulics.

The experience of the writer has led him to be opposed to any considerable amount of computing in the laboratory. As the work is planned in the Hydraulic Laboratory of the University of Wisconsin the average student's time and attention are fully occupied with the details of the experiment in progress during the two hour period. The calculations are more accurately and quickly made under the more favorable conditions of the computing room. Very little time need be lost in an effort to adjust points which are obviously wrong, for the instructor can readily recognize blunders in reading time, or weights, and other common errors. The greatest cause of lost time in the computing room is the hunting of errors due to careless calculating. This trouble would be increased if the computing were done in the confusion of the laboratory.

THE ARCHITECTURE OF ENGINEERING SCHOOLS.

BY JAMES M. WHITE,

Professor of Architectural Engineering, University of Illinois.

The principles underlying the science of planning large groups of buildings were well understood centuries ago, but their application to the special problems of the engineering college is a distinctly modern one, which, because of rapidly changing conditions with reference to the relation and importance of the different kinds of instructional and experimental work, requires a new solution every decade. The problem in its true magnitude has been confronted only where campuses have been entirely rebuilt, as proposed at the Universities of California and Minnesota, and in such rare instances as we have here in Pittsburgh in the Carnegie Technical Schools and the Western University of Pennsylvania. Other institutions have individual buildings splendid either architecturally or in their adaptability to certain phases of engineering instruction, such as the Russell Sage Laboratory at Rensselaer and the Carnegie Laboratory of Engineering at Stevens Institute, but most of them are examples of what is possible with limited funds on inadequate ground areas. The engineering building at the University of Pennsylvania is probably the best example in the world of an engineering college under one roof, and though the arrangement has its administrative advantages, with more ground available, the problem would doubtless have been solved very differently.

The single building plan is difficult to treat as an architectural unit because of the varied requirements with regard to story heights, lighting, free floor area, etc., for the several shops and laboratories. If class and drawing room exercises can be confined to the morning and shop and laboratory courses be programed in the afternoon, so as to avoid the interference due to noise and vibration, the plan is a feasible one. In general, however, the group plan is certain to meet with most favor for the following reasons:

1. The buildings can be isolated sufficiently* to diminish the fire hazard and they therefore need not be absolutely fireproof.
2. Laboratories which are objectionable because of noise, vibration or dirt can be isolated. Road laboratories with rattlers, locomotive laboratories and combustion laboratories are instances of the above.
3. The lighting and ventilating are simpler problems.
4. Story heights may be readily varied to suit conditions.
5. Materials and equipment can be more easily handled.
6. The expansion of departments is more readily accomplished.
7. Yard area can be available in immediate connection with each shop and laboratory.
8. The greater the diversity in the purposes to which buildings are put, the more advantageous the group plan becomes.

A successful group plan must be based on a comprehensive administrative plan. In most engineering colleges the departments offering courses leading to a degree, as C.E., M.E., E.E., etc., are the administrative units and buildings are provided for each, while in others, departments of instruction such as surveying, mechanics, structural engineering, hydraulics, etc., are the administrative units, and departments teaching work requiring similar housing are grouped together. The latter method makes the best classification for building purposes, because if one department expands into a new building, the space left will usually be suitable for the remaining departments to use.

A study of our most important colleges shows that in general the offices, class, drawing and computing rooms are in one building, and the shops and laboratories are more or less separated but contain offices, computing rooms and demonstration rooms. With small departments where there is only one section in the advanced courses, many instructors prefer to have the laboratory, recitation and drawing work in the same building; but this is hardly feasible with a large department where students from other departments are handled in some of the same courses.

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* At least 60 feet between masonry buildings with stone, terra cotta or metal cornices and slate roofs, provided the buildings are not over three stories high. Lower buildings may be placed a little closer.

There are no absolute standards for the design of the classroom type of building, though they are fairly uniform in arrangement. This is also true of shops, but with laboratories we find a very great diversity, which is not strange when we consider that mechanical engineering instruction requires laboratories for experiments on steam engines and turbines, internal combustion engines, heating and ventilating, refrigeration, compressed air, hoisting apparatus, oil, gas and fuels; and that electrical engineering education requires at least a dynamo laboratory, a high tension laboratory and an electro-chemical laboratory.

For a materials testing laboratory, including cements and road materials, we have about the most varied requirements imaginable; but even they are more nearly standard than are those for the hydraulic, railway, mining, ceramics, and chemical engineering laboratories, which present entirely new sets of conditions.

The most noticeable trend in the development of laboratory work is the demand for out-door space, which has a very important bearing on the selection of a site. The position of the engineering college buildings on the campus is usually near the power house, which is generally at the low point of the grounds. The large amount of power required makes this advisable, and a spur from the coaling track can be run into the laboratory yards. If there are to be two distinct types of building in the group, they should not be laid out in a single quadrangle, but rather in two groups, those of uniform height and style in one, and the laboratories and shop buildings in the other with plenty of out-door space which will vary from that required for lumber storage, a dry kiln and shaving bin in connection with the pattern shop, to several acres for a materials testing laboratory.

The area of six city blocks* would not be a too generous one for the purely technical instructional work of an engineering college expecting an enrollment of 2,000 students in the next ten years, assuming both shop and laboratory instruction to be given. The areas required in the several buildings for a given number of students will depend upon the arrangement of the program, the size of laboratory units, and the method of instruction. At Illinois the shops and laboratories are operated all day, which makes four shop sections possible. The accompanying table gives data concerning the area required per pupil in shops and laboratories, based upon the present facilities at Illinois.

Two years ago the University of Illinois, with both types of building in use five and one half days a week, had 120,000 square feet of net floor area (gross area minus walls and corridors) devoted to technical instruction in the engineering college in shop, laboratory and class room buildings, which was 100 square feet per student. Of this 69 square feet were in laboratory and shop buildings, and 31 square feet in class room buildings. Only five per cent. of the space in the laboratory and shop buildings was in class rooms. The net area in the shop and laboratory buildings was 88 per cent. of the gross area and in the class room type, 63.3 per cent. The relative gross areas may therefore be taken in round numbers at 77 and 49 square feet each per pupil. If, therefore, we should design the laboratories and shops as one-story buildings, and the class-room buildings as three-story structures, the ground area covered by shops and laboratories would be seventy-seven divided by one third of forty-nine, or 4.7 times that for class-room buildings, without considering yard areas. These figures apply only where the relative amounts of laboratory and shop work approximate those at Illinois, with about the

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* A total area of about 25 acres.

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same distribution of students in courses. They are not intended as designing data but rather to call attention to the fact that the buildings of secondary importance architecturally will predominate in the scheme.

A study of the recently built shop and laboratory buildings listed below shows that they have been designed as independent structures, probably because of the impossibility of conforming to the existing conditions. If this conclusion is correct it is the strongest possible argument for the need of a comprehensive campus scheme.

The most interesting points for comparison in these buildings are the type of cross section, the method of lighting, and the kind of floor construction. Shop and laboratory buildings have usually been one story high; forty to sixty feet wide; lighted by monitors as well as side windows; with the trusses spaced close enough to support line shafts, and with floors laid on the ground. The overhead belting interferes with the appearance of the room as well as with supervision and a twenty-five foot spacing for roof trusses is more economical than the ten or twelve feet necessary to support line shafts. The shop with a basement or with unit drive for the machines overcomes both difficulties. To secure a steadier light and wider floor spaces, the saw-tooth roof construction has met with favor, though at the sacrifice of architectural effect.

The laboratory cross-section is also undergoing a change and galleries are being introduced for lighter equipment. The height required for a traveling crane is usually sufficient to allow galleries with a height of ten feet below them, and the galleries need not project enough to interfere with the operation of the crane. This arrangement of space is also economical from the instructional standpoint because of the ease of supervision.

A second gallery might be built for calibration work if the first galleries are built heavily enough for the operation of small engines, pumps and dynamos, and the main floor be reserved for condensers, boilers, gas producers, refrigerating machinery, etc. Such an arrangement would be economical from all points of view, including the handling of equipment by the crane.

The floor construction is an important one to consider because of the heavy wear upon the surface, the need of rigidity, the readiness with which machines can be attached and the facility with which openings can be cut through for pipes and wiring. A reinforced concrete floor gives the rigidity, but is supposed to have many objections from the other standpoints, most of which are controverted in an article in the *Engineering Magazine for* April, 1911, entitled "Objections to Use of Reinforced Concrete."

The Aberthaw Construction Company, of Boston, has published a very interesting bulletin entitled "Wearing Surfaces for Factory Floors," which, though primarily a discussion of the relative advantages of granolithic and wood floors, gives specifications for other types, such as the composite floor with a tar concrete base, plank sub-floor and maple top flooring, and a wood top floor on a concrete base. Their conclusion is that the granolithic floor, if it can be properly warmed, is the most satisfactory and most economical and that the difficulty of fastening machines to the floor is very much less than generally supposed.

Some other problems about which we might well compare notes are sizes and spacing of drawing desks, and whether drawing rooms should be large enough for more than one section at a time, or whether the combined class and drawing room is best.

What kind of artificial lighting is best in shops? Probably flaming arcs if the roof is of the open truss type. What kind for drawing rooms, individual lights or reflected light? What for class rooms, etc.?

Can shops and laboratories be ventilated more satisfactorily by ridge ventilators, or by monitor sash?

Is it best to heat shops by plenum systems or direct radiation? Is a forced circulation hot water system more comfortable and economical than a steam system with temperature control?

Such descriptions as the following are exceedingly valuable, and every new engineering building should be described in a similar manner and commented on in the BULLETINS of the Society for the Promotion of Engineering Education.

The most recent shop and laboratory buildings are the Russell Sage Laboratory, described in the *Rensselaer Polytechnic Institute Bulletin* for June, 1909, Volume 8.

The Mason Laboratory at Yale, described in the *Yale Scientific Monthly,* November, 1910.

The Laboratory of Practical Mechanics at Purdue, described in the *Bulletin of the Purdue Alumni Association* for May, 1911.

The Mechanical Laboratory at the University of Nebraska, described in the *Nebraska Blue Print,* Volume 9, 1910.

The Robinson Engineering Laboratory is described in *The Ohio State University Bulletins* for October, 1908, Vol. XIII, No. 3, by Professor F. C. Caldwell on "The Laboratories of the Electrical Engineering Department," and for December 23, 1909, Vol. XIV, No. 5, by Professor E. A. Hitchcock on "The Laboratories of the Mechanical Engineering Department."

The Hydraulic Laboratory at the University of Wisconsin, described in the *Journal of the Western Society of Engineers,* February, 1908.

The shop and laboratory building at Kansas State Agricultural College.

The latter building has been designed as one wing of a future engineering building, and has a three-story head house and 25 foot laboratory bays, with saw-tooth roof construction. In the materials testing section, the height from the floor to the trusses is 33′ 10″. In the steam laboratory, the engines will be set up high enough to give ample piping space below them.

WENTWORTH INSTITUTE.

BY ARTHUR L. WILLISTON,
Principal of Wentworth Institute.

The purpose of this paper is to describe some of the problems connected with the housing, and the provision for future growth and expansion, of a new educational institution like Wentworth Institute. Many of these problems arise because of the particular type of work that this school purposes to do. A brief description of its educational plan will, therefore, first be given.

Wentworth Institute is a school to "furnish education in the mechanical arts" according to the will of its founder, which means that it is a high-grade trade school of the kind that places its teaching all upon a rational scientific foundation, and supplements the practical training in shop-work with elementary technical instruction. Its aim is to develop artisans and skilled mechanics of a superior type, and also to train men who wish to become inspectors, shop foremen, master mechanics and superintendents for industry.

In looking over the possible field that a school of this grade might occupy a very great variety of branches and sub-departments of industry are found for which courses might very properly be established. It is difficult to choose those that are of most fundamental importance, and entitled to consideration in an initial plan; and it is still more difficult to determine with certainty the list of those that it will become desirable to develop as the institution grows. The plan for future expansion, therefore, must be kept extremely flexible. In order to have some definite goal for the institution to grow toward, however, a plan was adopted, after much consideration and study, which provided for an ultimate scheme of twenty-six day courses and a still larger number of evening courses.

In the initial group of buildings, it was decided to include three types of courses: first, short practical courses of apprenticeship grade, intended for beginners and persons who have had little practical experience; second, longer and more thorough courses, at least two years in length, intended for persons who hope to rise to positions where they will be required to direct the work of others; and third, evening courses of a very practical character, given in both shops and laboratories, but planned for persons employed in similar lines of work during the day and intended to supplement their daily experience.

The list of courses is as follows:

One-Year Day Courses.

Intended for beginners and persons who have had little practical experience.

Manufacturing Trades:

Machine Work,
Pattern-Making,
Foundry Work.

Building Trades:

Carpentry and Building,
Electric-Wiring,
Plumbing.

Two-Year Day Courses.

Intended for those who wish to become superior workmen, master mechanics, foremen, etc.

Machine Construction and Tool Design,
Electrical Construction and Operation.

Evening Courses.

Intended for those who are employed during the day.

Carpentry and Building,
Pattern-making,
Machine Work,
Tool-Making,
Foundry Practice,
Electric-Wiring,
Plumbing,
Practical Mathematics,
Mechanical Drawing,
Machine Design,
Practical Mechanics,
Strength and Properties of Materials,
The Steam Engine and the Operation of Power Plants,
Electrical Machinery.

The initial problem for the architects was to provide shops, laboratories, drawing-rooms, and class-rooms for these eight-day courses and the corresponding evening courses. The type of instruction that it was proposed to offer influenced the buildings very largely. The shops and large laboratories are the predominating feature in all of the instruction. The drawing-rooms and the class-room instruction are essential but occupy a relatively small place in the completed plan. The one-year and the two-year day courses are intended for different types of students and consequently differ considerably in character and in the distribution of time to the different kinds of instruction.

A typical curriculum for one of the one-year courses would contain the following subjects and approximately the following distribution of time:

(1) Computations and shop calculations, and practical applications of mathematics to various problems related to the particular trade	5 hours per week.
(2) Applied science, recitations and demonstrations	3 to 5 hours per week.
(3) Applied science laboratory instruction on problems related to the particular trade	4 to 6 hours per week.
(4) Blue print reading and elementary mechanical drawing	6 hours per week.
(5) Shop practice	20 hours per week.
	Total number of hours per week 40.

A typical curriculum for one of the two-year courses would be approximately as follows:

FIRST YEAR.

(1) Computations and practical applications of mathematics to various problems related to the courses	5 hours per week.
(2) Applied science, recitations and demonstrations	5 hours per week.
(3) Applied science laboratory instruction	12 hours per week.
(4) Mechanical drawing and detail designing	6 to 10 hours per week.
(5) Shop practice in fundamental trades	12 to 16 hours per week.
	Total number of hours per week 40.

SECOND YEAR.

(1) Practical mathematics continued................5 hours per week.
(2) Applied science and elementary technical branches, recitations and demonstrations......................5 to 8 hours per week.
(3) Applied science laboratory instruction in chosen specialty 8 to 16 hours per week.
(4) Detail designing.......................6 to 12 hours per week.
(5) Advanced shop practice in chosen specialty..8 to 16 hours per week.
Total number of hours per week 40.

If the architectural problem had merely been to design a group of buildings that would adequately house the eight courses of instruction that Wentworth Institute will organize, September, 1911, it would have been a comparatively simple one, but it was necessary to provide for the future growth. This growth is likely to be of two kinds. First, the courses that are now being started will grow and demand more room and larger shops and laboratories; and second, new courses preparatory to additional trades and industries will undoubtedly be established. It is impossible to tell with certainty how many new courses will be required and just what occupations such new courses will prepare young men for. The careful preliminary survey of the field indicated that it was desirable to make provision in the plans for the fully developed institution, after it had grown to the full limit that the present endowment could support, for a list of twenty-six courses divided into four principal groups; but this list, of course, is likely to be added to or subtracted from. About half of these courses are one-year courses of the type intended to train artisans and superior workmen; the other half are two-year courses intended for persons who hope to rise to positions of the grade of foremanships or superintendencies.

As provision must be made in the future, for housing of many and perhaps all of these additional courses besides providing for the growth of the courses now being started, the problem presented to the architects was not only to design an initial group of buildings, but to arrange these buildings so that they may be continuously added to as the institution grows, and at the same time always give convenient and well arranged floor space for the related departments, on the inside, and a pleasing and symmetrical architectural design and composition on the outside.

Fortunately the site which had been purchased for Wentworth Institute gives ample room to provide for such a possible future development, as it contains between twelve and thirteen acres of land; and the endowment, too, is sufficient to care for a considerable growth. It amounts to about three and one half million dollars exclusive of the site.

In designing buildings for Wentworth Institute many of the same considerations that would influence the design of buildings for an engineering school or university would, of course, apply, but, because of the practical field of education in which Wentworth Institute is engaged, an unusual degree of emphasis must be placed upon certain of these, while comparatively little weight need perhaps be given to others. New considerations, too, that would not apply to schools of a different type, needed to be taken into account. The following extracts from the list of suggestions given to the architects at the beginning of their work will be of interest.

1. All of the departments of the Institution should, in appearance and general arrangement of equipment, resemble as closely as possible corresponding departments in commercial manufacturing plants.

2. The Institute should set a high standard in efficient use of floor space and in its plan for simple and direct travel of material and workers from sub-department to sub-department.

3. In order to control the entire student body of a large trade or elementary technical school such as Wentworth Institute, a single entrance or exit close to the general administrative offices of the Institute and in a central building should be provided where pupils from all departments may be required to enter and leave the school.

4. So far as possible the same idea of student control referred to in paragraph No. 3 should be applied in the design and arrangement of the rooms of all sub-departments occupied by students in any given course.

5. As it is probable that some departments of the school will grow and develop much faster than others, it should be possible to provide more

space for them without interfering with the arrangement of other departments or detracting from the architectural effects and the attractiveness of the campus.

6. As large quantities of heavy material must be delivered at frequent intervals to many of the large shops and laboratories, convenient means of delivery must be provided, independent of the main entrances and hall-ways of the buildings.

Every attempt made to design the shops, laboratories, and class-rooms needed for the initial group of courses, and at the same time to provide for the growth into a larger scheme, developed the fact that very few departments of the Institute could be regarded as permanently located on any given floor space. Occasionally some department will be forced to move to make room for the growth of others. In order to accomplish this with as little cost and inconvenience as possible, the best plan found is to follow that adopted by many large manufacturing plants and department stores of providing unobstructed floor space that may be re-arranged and sub-divided at very little expense to suit the changing needs of the various branches of the business.

Of all the methods tried, the best solution was found to be in the adoption of a *standard unit,* or standard building which may be repeated again and again in various locations on the campus. This unit was so chosen that it could be easily and conveniently doubled or trebled or multiplied any number of times. It was also chosen of such dimensions as to permit its convenient division into offices or small class-rooms or good sized lecture rooms or science laboratories or large laboratories and shops by the use of temporary partitions.

A great variety and types of buildings were carefully studied. The advantages and disadvantages of each were considered. The one finally adopted was a three-and-one-half-story and basement building, 48 ft. wide by 144 ft. long, divided into nine equal bays of 16 ft. each.* A typical floor of this *standard unit,* when used for shop purposes, is shown in

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* All dimensions are given to the center lines of the walls or partitions.

Fig. 1. The second floor plan of this standard unit, divided into offices, recitation and lecture rooms, wash-room, instrument room and laboratory, is shown in Fig. 2. It will be noticed that the floor space, with the dimensions chosen, may be divided readily into rooms of convenient size. Where shops or large laboratories or drawing rooms are required, the full width of the building is used, and the rooms may be 32 ft., 48 ft., 64 ft., 80 ft., 96 ft., or 112 ft. long, as desired. Where recitation or lecture rooms are required, a corridor about 8 ft. wide is run on one side of the center row of columns, making rooms 24 ft. wide on one side of the building, and about 15 ft. or 16 ft. wide on the other. Recitation or lecture rooms are naturally made 24 ft. by 32 ft., or 24 ft. by 48 ft. Both of these are very convenient sizes. The narrow space on the other side of the corridor, too, divides itself

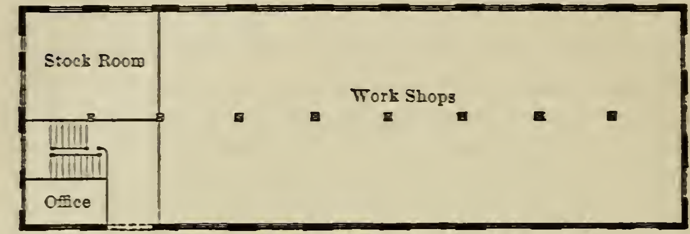

FIG. 1. The *Standard Unit* Divided for Instruction in Shop Practice.

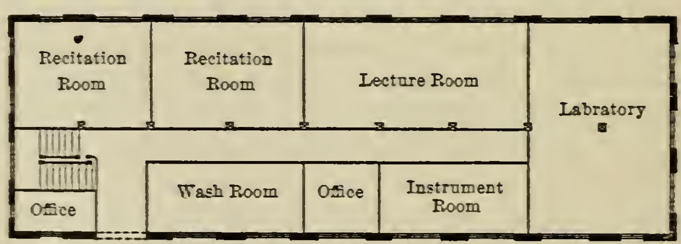

FIG. 2. The *Standard Unit* Divided for Recitation Rooms, Lecture Rooms, etc.

readily into offices 16 ft. square, or instrument rooms, wash-rooms, etc., 16 ft. by 32 ft., or 16 ft. by 48 ft. It would be difficult to select dimensions for a standard building which could be divided more readily into rooms of convenient size for all sorts of purposes.

Attention should also be called to the selection of a standard building with *nine* bays, and having a width equal to the length of three of the bays. In the first place, the nine bays make it possible to have either one entrance in the center of the building, or two entrances symmetrically located near either end, without having a column on the axis of the entrance. Having the width of the unit equal to one-third of its length, makes it possible to extend a wing to the rear in the center of the building, making a "T"-shaped building, or else to extend two wings to the rear at either end of the building, making a "U"-shaped building, as is desired. If the width of the building was not equal to an even multiple of bays, this could not be done without re-arranging the window spacing. If, too, a smaller dimension than 48 ft. by 144 ft. were chosen, the space between the wings would hardly be sufficient for proper lighting.

The excellent lighting and the general arrangement of the windows and the type of elevation adopted for the standard building, are clearly shown in Fig. 3, which is a photograph of power house and one completed unit. Fig. 4 shows a rear view of the buildings already erected, which include a foundry, one of the standard units, a two story wing about 24 ft. by 48 ft. to connect this unit with the future administration building, and a power-house about 80 ft. square. On the block plan shown in Fig. 5, the completed buildings are shown at *a*, *B*, *C* and the power house.

The departments that have been provided for in these initial buildings are as follows:

In the attic, lighted from above by the skylight, a practical mechanics laboratory, 48 ft. sq. with two large stock-rooms.

On the third floor, an electrical wiring shop, 24 ft. by 64 ft.,

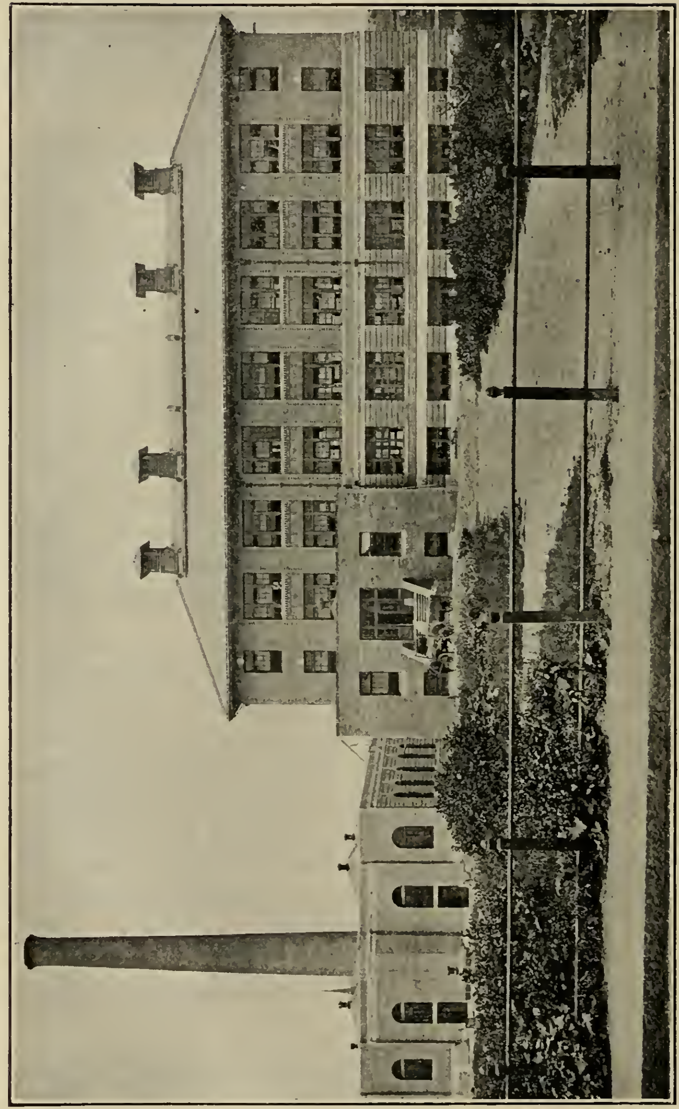

FIG. 3. The Initial Buildings of Wentworth Institute.

a plumbing shop, 24 ft. by 64 ft., a large lecture room, two recitation-rooms and three offices.

On the second floor, a drawing room, 32 ft. by 48 ft., a carpenter and pattern shop, 48 ft. by 80 ft., a recitation room and two offices.

On the first floor, the administration offices, machine shop office and stock-room, a machine shop 48 ft. by 80 ft. and a machine design room 32 ft. by 48 ft.

In the basement, which has the same height and lighting as the other floors, is a building materials laboratory, a forge shop, the locker and wash-rooms and certain rooms belonging to the foundry department.

The foundry wing, shown in Fig. 4, is two stories high and gives a working floor space of 48 ft. by 72 ft. with a gallery having a little over half this area. In addition to the working floor space, there are provided in the adjacent portion of the basement of the main shop building a foundry office, a casting cleaning room, a tool-room, a supply room, and a small chemical laboratory for foundry-chemistry.

The power house is designed to provide for a very considerable future growth. At the present time, it contains a 200-k.w. generator direct connected to a Corliss engine and a 250-h.p. water-tube boiler. There is room, however, in the plant for a 1,500 horse-power boiler and apparatus to generate an equal amount of electrical energy. Until more space is required for future power plant equipment, however, the space is being utilized in the boiler room, a steam laboratory, and in the engine room for a dynamo laboratory—the plan being to have a railing separate from the apparatus required for power service from that used in experimental work.

Fig. 5 shows in outline the plan that has been laid out for the future growth and development of Wentworth Institute. As has already been stated, the buildings at present in use are the power house, *a*, *B* and *C*. The main administration building, for which working drawings have already been prepared, and which will be the next building erected, is shown at *A*. The buildings, which in the natural course of events,

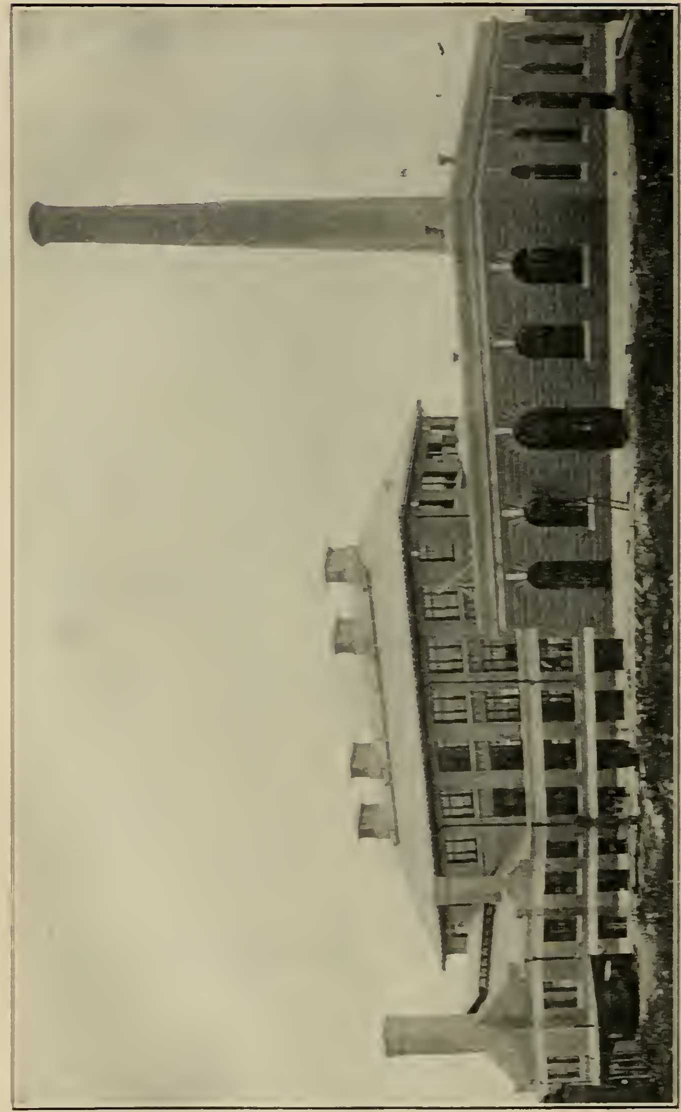

Fig. 4. Rear View of Wentworth Institute, Showing Foundry, Shop Building and Power House.

will probably be erected next, are *a, D* and *E*. When this number of buildings have been completed, there will be a symmetrical structure with a dignified entrance and an entrance court of sufficient size to make an excellent appearance.

Sufficient room has been provided on all sides of the group described in the last paragraph to permit extension in any direction; for example, the wing *B* can be extended in length for 96 ft. It can then have a second and third wing parallel to the wing *C* extended at either end of it for a distance of 96 ft.; and these two wings may be connected together in the rear by another building running parallel with *B*, forming a

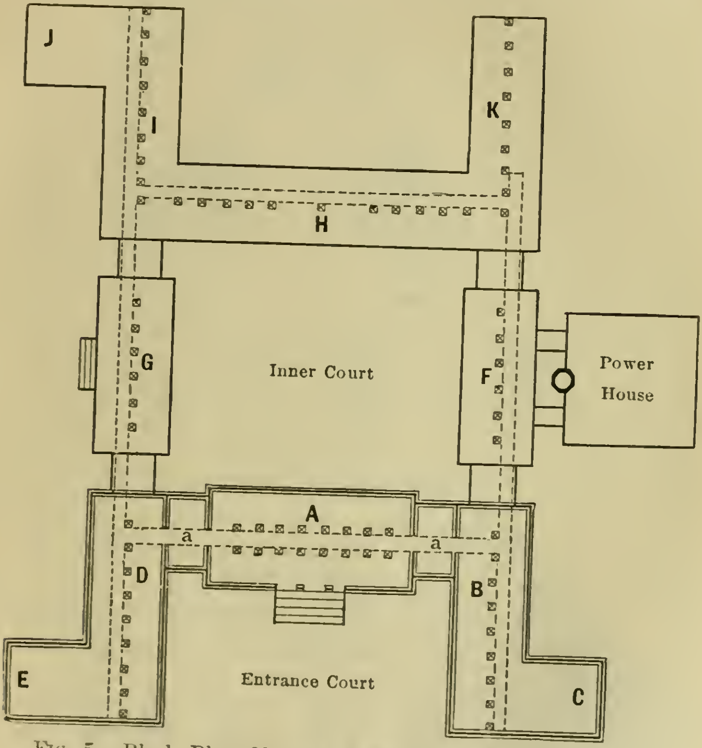

FIG. 5. Block Plan Showing Possible Future Development.

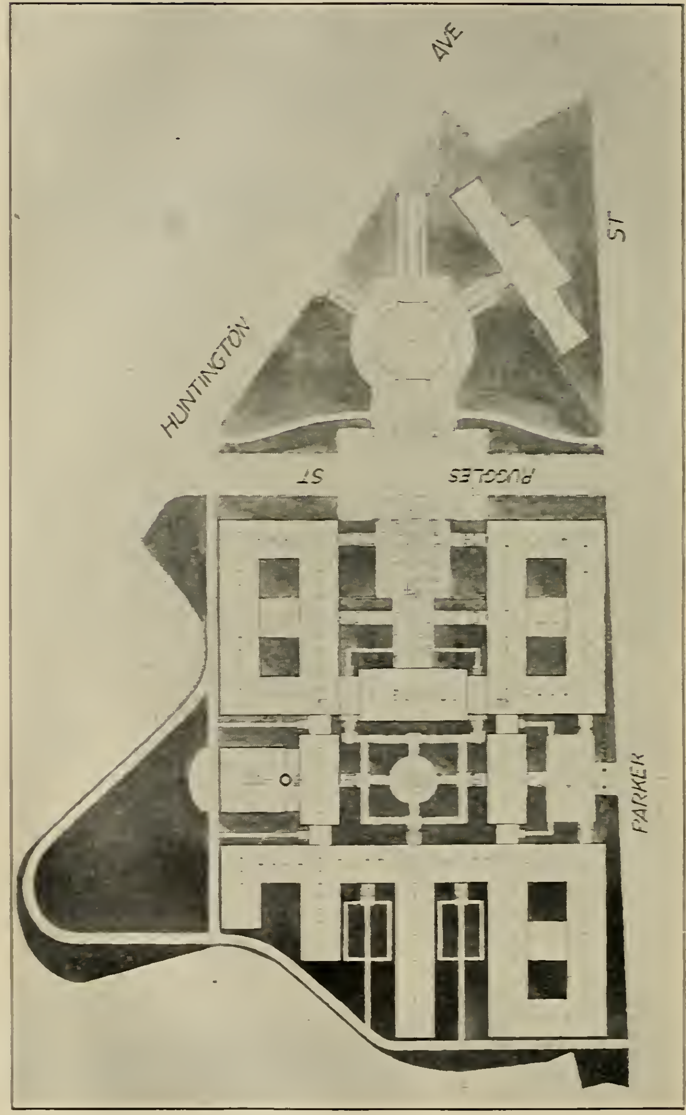

FIG. 6. The Architect's Completed Block Plan.

completed rectangle with two hollow courts 48 ft. sq. If all of these additions were to be made, the completed structure would have a floor space equal to four and one-third of the standard units adopted. But of course, it is not necessary to complete the whole of the buildings. The great variety of ways in which growth can take place shows the flexibility of the plan.

After completing the front group of buildings shown in Fig. 5 at *EDaAaBC*, it is probable that, in place of extending the front as just described, the next development would take place toward the rear, erecting buildings shown at *F*, *G* and *H*. This would create an inner court somewhat larger than the entrance court. At the rear of this, there is still room for additional building, indicated at *K*, *I* and *J*.

Fig. 6 shows the completed block plan as laid out by the architects (Peabody & Stearns, Boston), with buildings indicated at every point where there is space to erect them. In studying this plan, however, it should be kept in mind that it is not necessary for all of the buildings here indicated to be erected, for example, the whole of the front might be completed as indicated in Fig. 6, leaving the rear entirely undeveloped; or, on the other hand, only so much of the front might be completed, as is shown in Fig. 5, and a considerable portion of the rear completed in addition.

One or two more points in the plan shown in Fig. 6 are of sufficient interest to warrant some attention. These are: first, the ease with which it will always be possible to keep a symmetrical arrangement of buildings as the Institution grows after the front group is completed; second, the ease of control of the student body on account of the single entrance and the simple system of corridors connecting together the various buildings; third, the central and convenient location of the administration building, always near the center of the entire group; fourth, the excellent provision for light and air, and fifth, the impressive approach from the parkway opposite.

Discussion.

Mr. Kent: I would like to ask what are the particularly good features of the electrical laboratory at Worcester. Professor White said it was good architecture. In what particular is it good architecture?

Professor White: It is a little difficult to put one's finger on just the one thing which distinguishes one building which is good from another building which is bad. But, generally speaking, proportion has more to do with it than anything else. If we were designing a building, for instance, which is to be viewed from a distance there are two things which are of paramount importance: light and shade and outline. Outline, of course, will show on the picture; light and shade often will not. The detail will not show at a distance. If one can get a good, heavy projecting cornice which will give light and shade, that helps wonderfully. With a good color scheme and a good relation of warm masses there is good architecture. If a building comes up rather close to the street, and therefore is to be viewed close at hand, possibly by craning the neck and looking up to some extent, far more attention must be given to the cornices. In the building at Worcester the great satisfaction to me is in the simple lines of the projecting cornices, in the arrangement of the windows, in their relation to the building, and in having an adequate approach. I have seen instances where the entrance to main buildings was through three or four foot doorways at street level. These entrances look like back doors. An important building is worthy of an important and impressive entrance.

Mr. Kent: I was particularly impressed with that Worcester building when I was there, and as I indicated my good impression to my guide I said, "I do not see any signs of an architect around this building." The reply was, "No, we didn't have any architect around it until the end." The building was designed on utilitarian ideas. They wanted a building to accommodate the professors in doing their work. They wanted a railway through the building and they got it.

with a big doorway to come in through. They wanted light and they got it, through ample windows. Red brick was cheapest and therefore it is red, a very good color. It was in a ravine surrounded by trees and could not help being beautiful if the architects put a suitable roof on it.

Professor Hibbard: I would like to ask Professor White to answer a general question. As an engineering professor, what has been his experience regarding the library and its use? I notice that much emphasis seems to be given in many plans to a great central library building, which I assume is intended to contain the books of all the colleges or departments of the university. It has been my experience as an engineering teacher that if we expect to get engineering students to make the most thorough use of the books in the engineering library, we must take the library to the students and not expect them to go off into some great central library building. For example, at the University of Missouri, our engineering students like to go into our engineering library, located in the engineering building. They go directly to the book shelves. They go in there without coats if it is warm weather, and do not care to go over into the general library to work among the women from the college of arts and sciences. Furthermore, the men of the school of engineering, perhaps because of laboratory work, are usually rather less expensively dressed than those in the college of arts and sciences. Our school of law has its library in the law building; the medical school, in one of the medical buildings; and in our recently completed central building for the college of agriculture, the agricultural students have their library. All of this rather leaves the great general library for the college of arts and sciences, and the school of education, enrolling 1200 and 200 students respectively. I would like to know if in general, in the new plans for these axial campuses* of the future, it is one of the essential things in the minds of the architects that all the different libraries should be located in one great central library building.

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* In his lecture Professor White explained that in several of the new campuses the buildings are located as nearly as possible symmetrical with respect to an axis.

To emphasize my thought I repeat that I believe, in order to make the students of the different schools use the library books thoroughly and at those times when they can have opportunity, these books must be exceedingly accessible. Between recitations and laboratory periods they may be consulted, or a student may slip away from the designing rooms or laboratories to consult three or four books on a subject connected with the matter in hand. I believe that most engineering professors would rather see the libraries taken to the students, than to have a splendid, great central library built for all library books: workshops, rather than a mausoleum. May I ask the speaker to comment upon this subject?

Professor White: The question raised is of course a very important one, and the answer varies with conditions. It is not necessary, from the architect's standpoint, to have a separate library building; but there are a great many advantages from the administrative standpoint of having the central library building. Possibly as the library grows the importance of having a central library building becomes more and more important. I believe that every department in a university which has what might be termed an independent collection of books should have its own library. By that I mean the law school and possibly the medical school. But when you go beyond that and attempt to provide separate libraries for the several departments, you begin duplicating books to a very great extent; you begin increasing the cost of the administration of that library to a very great extent. It begins to be necessary for you to keep all of the buildings of your campus open night and day, so that students may consult those books scattered around through the various buildings. Students do less systematic work in the library by rushing into it to consult a book to get a bit of information between classes or while working in the laboratory, than they do if they go to the library, notebook in hand, to study up on certain subjects, to make memoranda in their note-books to which they will refer when they go back to the class-room or the computing-room. I certainly, therefore, believe a central library is the proper thing, though I would supplement it, wherever possible, by reading rooms in the various departments; those reading rooms, however, having only the current periodicals and a few standard reference books and encyclopedias, dictionaries, etc., which may reasonably be duplicated, because they would have to be duplicated in the general library. But when with standard sets of periodicals and reference books, any university library, to be at all adequate, must run up into the hundreds of thousands of volumes, and no student can find the things which he wants in a department library, because the engineer must consult the same books as the students of physics and other students of science do. If he gets in the habit of going to the general library he will go there, whereas, with a department library, he is inclined to think that the only information he can use and the only facts he can know are in the departmental library. He should get into the better habit of going to the main source for all things.

Professor Hibbard: During the period of my connection with Cornell University, in the college of mechanical engineering we at first had a college library. As a number of the teachers believed that engineering books should be in the central library, so that students would get in the habit of going to that great central library, the books were moved there. The result was that the students did not form the habit of going to the central library, but simply got along with what books they had in their own rooms, their text-books, and neglected consulting the collection of engineering books in the general library. Not long previous to my leaving Cornell it was decided to be advisable to establish a Sibley College library for the mechanical and electrical students, with some simple restrictions and care to make it a working library. We kept track of the books that were used, and if one was not used a reasonable amount it was taken out of the special Sibley College library and returned to the general library. The result was that our students became users of the engineering library, as they had not been users of the engineering library when it was distributed among the other books contained in the general library of the university.

Director Hamerschlag: Just a word on the question of the library as a part of the comprehensive plan for buildings and education. I wish to speak on this subject because it is one of our big problems.

The Carnegie Library, which is housed in the Institute building, contains about 250,000 volumes and has a reference collection of 80,000. The distance between the technical schools and the Institute is perhaps 1,500 feet. It is extremely difficult to get students to go to that library for minor reference works and we have found it necessary to place in the department which requires reference books, such texts and reference literature as is important and we consider this equipment as of the same class as working tools used in the same way as laboratory equipment, but for general study and for general reading there can be no question but that the atmosphere of a good library such as the Carnegie Library, does have its influence on the students and is effective *in* attracting the student to more wide spread interest in general literature.

We have hoped that we might some time have a separate branch of the general library located within easy access of each of the four schools and which would contain a reference collection with more direct reference to the arts, sciences and industries which form a part of our curriculum than could be available if we were dependent upon this collection to be purchased and maintained by city funds.

Pending this happy outcome, we have been studying the question of a mechanical book-carrying service from the Library into each of the buildings. It seems, as Prof. White has aptly said, unwise for administrative reasons to organize three or four separate libraries, but as not more than ten per cent. of the books in any one library can ever be adequate in the way of service to a group of students studying a particular subject, the other ninety per cent. ought to be near at hand when needed.

Professor White: Professor Williston says that, at the Wentworth Institute, they are going to have class-rooms and drawing-rooms as directly connected with the laboratories as is possible. I think there are a good many objections to that class of a laboratory; but it is the man who is doing the teaching, of course, who must decide that question. And it has always seemed to me that in designing a building for the advanced classes it is best to have simply an administration class room in connection with each shop or laboratory, and that all the other work would be more efficiently done in separate buildings.

Mr. Kent: There is one serious objection to having the class-room very closely connected with the shops, namely, that the noise and vibration of the shop interfere with the class-room. I had occasion to be acquainted with that fact, in one case where it was necessary to shut down the machinery in the shop in order to have a class exercise carried on properly. The class-rooms therefore should be in a building separate from that housing the noisy machines.

President Talbot: There is one point that might be emphasized farther, it seems to me, in regard to campus development,—the importance of having sufficient area in connection with our engineering college buildings, particularly in connection with our laboratory buildings, for what may be called back-yard space for storage and other purposes. We have been shown by Professor White the attempt which is made to give a good impression to the visitor as well as to the student. And yet there are unsightly operations connected with an institution which attempts research that properly goes with instruction. For example, in certain investigations material must be left out-of-doors for a considerable length of time, track space will be needed for bringing materials to the laboratories and for other reasons a large space must be provided. It seems to me, too, that the suggestion made by Professor

White is a good one, that while we may have in our main campus a general grouping of buildings to give a good appearance, there should be on the outskirts, or in other portions of the campus territory, the opportunity to have smaller buildings and spaces of different character; and this applies not only to engineering buildings but to those used by the science group, by the agricultural group and by other departments.

Professor Wm. T. Magruder (by letter): The reference by Professor White to memorial laboratories and buildings suggests the question, Should boards of trustees accept gifts for buildings if the buildings are to be permanently named after the donor when the funds received are inadequate for both present needs and future growth? Should a donor be permitted to stunt the growth of a department or a college, and make it his tombstone, by donating an inadequate sum of money for a building to be forever called by and labelled with his name? Few people desire to give towards the enlargement of Mr. Blank's Memorial of Himself, or to "The ——— Laboratory of ———"; yet, the department housed therein may be required for years to put up with crowded conditions and inadequate facilities in honor of a highly respected and well-intentioned donor. In the long run, may not the price paid be excessive? I am informed that, once a gift has been accepted for a specific use, it is not lawful to divert it to some other use, regardless of the desirability and wisdom of so-doing. Donors should remember, and be reminded when necessary, that children's clothes are sometimes outgrown and have to be either given away or sold to the ragman, and that therefore they should not insist too strongly that the child shall always wear the donated clothing regardless of its fit and suitability, and that large discretionary powers should be left to the child's parents or guardians.

Dean F. L. Bishop (by letter): The paper by Professor White on the "Architecture of Engineering Schools" shows that the author has made a very close study not only of architecture, but of the organization of schools. Perhaps I can best discuss this paper by outlining in a brief manner the plan for the engineering school at the University of Pittsburgh. The plan consists of a central building comprising the executive offices and an assembly hall of sufficient capacity to accommodate approximately one thousand students. This is to be located at the center of a triangle, two sides of which are taken up with buildings devoted to recitation, drawing rooms and laboratories, while the other side is to be occupied by buildings for shop and special laboratory purposes. This provides a very convenient arrangement whereby the executive offices are located at the center of the group and the recitation rooms are easy of access from all parts of the group. The buildings at Pittsburgh are located at the foot and on the side of a hill, permitting the use of many different types of buildings, so that all kinds of engineering work can be provided with the types best suited for their work.

Another important point to which Professor White calls attention is that of outdoor storage space. This undoubtedly should be provided for to a greater extent in the future than it has been in the past. By storage space, Professor White, of course, means to include space for the erection of temporary buildings that can be used for special purposes, as for instance, a smoke laboratory, a fire proofing laboratory, etc.

I agree with Professor White in the suggestion that the plans of all new engineering school buildings should be published by the Society.

Director John P. Brooks (by letter) : As most institutions are not in positions to utilize their funds otherwise than for strictly utilitarian purposes, the questions of first cost and maintenance are of vital importance. The group system, discussed by Professor White, carries the necessity of duplicating roofs, and to a certain extent, the foundations, and, especially if land values be high, must involve a greater first cost than the unit system. The cost of building construction increases somewhat, with the height above the ground, but not very rapidly within the limits usually found in college buildings. Ventilation, heating and lighting should, in general, be less expensive in single buildings than in groups involving the same floor space. The same is true to a certain extent, in plumbing and sewer and water connections with the street. Much of the maintenance charge is due to faulty roofs, and should be correspondingly less in one than in many such areas.

Insurance rates would vary slightly, favoring probably the group system, since the rate for the large building would be determined by the risk in the most exposed room or department. Should a fire loss occur it would be more apt to be serious in the large building both as to property and as to inconvenience.

Taken all in all, it seems probable that reasonably high buildings are economical in first cost, in operation and in maintenance.

The question seldom is whether there shall be one building or ten buildings but as to much less latitude of choice. While some local conditions fix the plan definitely, there seems to be considerable opportunity to combine the best features of both systems. It is quite essential that the work of students be always within appropriate surroundings, but this does not mean that every subject taught needs the inspiration of a special type of architecture or of mural effect. Most of the recitation work of the under classmen may be properly done in one building, even if the institution be one of considerable size.

The rooms used by the various departments of science, both for recitation and for laboratory work, may with advantage be under one roof.

The drafting rooms for engineering students are, appropriately, near the shops and testing laboratories and may be placed over them without fear that the noise will be unduly distracting. On the contrary, such environments may prove an incentive, as they represent conditions found in practice.

Other groups of subjects to be cared for under one roof may be readily called to mind.

With several, but not an excessive number of buildings, the style of architecture may be selected with regard to fitness rather than to uniformity alone.

Students naturally and unconsciously respond to the influences of the rooms in which they work, and so buildings suggesting the mood most favorable for the reception of instruction should, as far as possible, be provided. Hence, undue elaborations, either outside or inside, in structures devoted to shop and laboratory work, should not be allowed to divert funds that could be used to better advantage in making one or more buildings on each campus, works of art as well as of utility.

Mr. William Kent (by letter): In discussing Professor White's contribution, I have no comments to make on the paper itself, except to say that it is a valuable and suggestive one, and one that should be read by everyone who is about to have anything to do with planning buildings for an engineering school. I may, however, contribute some of my own ideas on the same subject.

Architecture is two different things, (1) planning for beauty, and (2) planning for utility. An architect may be either an artist architect, whose main idea is beauty or what he thinks is beauty, or an architectural engineer, whose main ideas are utility and economy, and whose artistic sense, if he has any, has not been developed so far that he can embody it in his utilitarian plans. Rarely is it possible for the two kinds of architect to be combined in one man. The artist architect's mind is trained with reference to Greek temples, Roman palaces, Gothic cathedrals, renaissance villas, Spanish missions, colonial residences, classic mausoleums, state capitols, etc. The engineer architect is trained to consider the questions that Professor White suggests: "what kind of artificial lighting is best for shops," "plenum systems and direct radiation," "granolithic floors," "saw-tooth roof construction," "height required for a travelling crane." "outdoor space and room to grow." The attempt to make both kinds of architect out of one man leads to his failure in one or other of the two great branches of the profession, and often to his failure in both. The result is, that architecture tends in its artistic side to be degraded into mere millinery, the design of a structure that is supposed to "look pretty" and be in the fashion, but has no artistic merit, and on the engineering side to the design of a structure poorly adapted for its utilitarian purposes. The case is still worse when college presidents, boards of trustees, and donors of buildings turn themselves into amateur architects, and boss the architect whom they employ to carry out their ideas. A large university built on this method began with a fairly good building of the 1870 type with a mansard roof and a tower, followed by a fine Richardson-Romanesque structure of brown stone, a gift of a millionaire; then by a nondescript red brick cheap building, a dark stone building, perfectly plain, that looks like a jail; a monumental renaissance structure of grey brick with stone trimmings, costing $200,000, with a majestic stairway and corridor, but with poorly arranged classrooms, and large auditoriums without ventilation; a library of the Greek temple style with the reading room surrounded with imitation sienna marble columns, and no ventilation; a laboratory the style of a barn, and so on. The whole is a mongrel collection of buildings with all the architectural fads of the last forty years, and all in a vast campus unprovided with trees which might hide their incongruity. From an engineering point of view, they are equally bad. All are without modern systems of ventilation, and some of them are fire traps.

Fortunately this method of building a university is disappearing. Fine examples of a better way are those mentioned by Professor White in his paper, and Columbia University and Leland Stanford University might be added to his list.

My idea of the way that a building or a group of buildings for an engineering school should be planned is the following. The preliminary tentative plans should be made by the professors who are going to use the buildings. They should determine the floor space needed for each class room, lecture room, drawing room, laboratory, offices, halls, stairways, etc., the height of ceilings, the size and position of windows and blackboards, the requirements for power, heat, ventilation and artificial lighting, and they should make two or three dimensioned sketches showing different arrangements of rooms and shape and grouping of buildings. Provision should be made for easily removing the partitions so that two or more small rooms can be made into one large one, or a large room divided into two or more small ones. The ground plan should be made with reference to future growth, which may be met by extensions of one or more buildings, or by the addition of new buildings to the group. When the sketches are finished, after long study and discussion, a committee of professors should make a trip to visit several of the most progressive universities to get ideas which may be incorporated in the revised plans and sketches. These, together with a typewritten report covering all matters that are not clearly drawn in the plans, including the reasons for adopting the dimensions, arrangements of rooms and other details, should then be turned over to an architectural engineer who will proceed to design the buildings in accordance with the sketches and instructions given in the report, and with reference to utility without regard to artistic appearance. This design should then be given to an artist architect, or to a commission of two or more of them who would provide the proper façade for the buildings, determine the kind and color of the outside material, and furnish details for the interior decoration. In this way the final results should be satisfactory both from the point of view of the architect and that of the people who are going to use the buildings.

Professor Geo. C. Shaad (by letter): As stated in this paper, the preferred plan for the housing of an engineering school appears to be to have one building which shall contain the administration offices, an assembly hall, and class and drafting rooms for the accommodation of a large part of the instruction which is common to all of the engineering courses; and to use separate buildings for the more important or extensive laboratories and shops. Certain of the laboratories may well occupy the basement or wings of the main structure but others are preferably placed in separate buildings.

In the case of engineering schools connected with state universities or colleges the above plan is the most practical one, and such departments as cannot be supplied with their own laboratory buildings at first may be accommodated temporarily in the main or other laboratory buildings. The additional buildings are added as the school expands and the space vacated in the main building becomes available to take care of the growth in the number of students for which recitation and drafting rooms must be provided.

The plan of making a laboratory building for a separate department large enough to accommodate class and drafting rooms for the department subjects and offices for the instructors who devote all of their time to these subjects has much to commend it, except where the nature of the laboratory work is such as to interfere with the conduct of recitations held in the same building. Each department becomes a unit and the rooms in the main building are still further relieved. This plan is followed with success in some large manufacturing plants where the engineering offices and drafting rooms devoted to the production of some particular portion of the product occupy a part of the factory building or group of buildings devoted to this work, and a main or central office building is used only for the departments which are common to the plant as a whole.

The engineering school of the University of Kansas is following the plan of one central or main building (Marvin Hall) with separate buildings or parts of separate buildings for the more extended laboratories. The department of hydraulics and the electrical engineering department are as yet only temporarily accommodated but the general plans allow for a separate building, or separate sections of a large single-story building, for these departments.

In planning a laboratory building it is well not to lose sight of the fact that along certain lines of work it is very desirable that a certain number of comparatively small rooms be included for use in special investigations where apparatus may be set up and, if need be, left undisturbed for long periods of time.

Dean E. B. McCormick (by letter): We have, at the Kansas State Agricultural College, been attempting to solve some of the problems mentioned in Professor White's paper, and believe we have secured fairly satisfactory results in at least some of the cases.

The departments of architecture, civil engineering, steam and gas engineering, applied mechanics and hydraulics, and power and experimental engineering, and the engineering experiment station, are housed under one roof, but this roof covers what is practically a series of buildings rather than a homogeneous unit. The original building was the second of any size to be built on the College campus, and was turned over for shop purposes after having been used for general college purposes. It contains, on the first floor, a portion of the woodworking department, and on the second floor offices and recitation rooms. Two story additions have been added to this, the first floors of which are given over to woodwork and one of the second floors being used as a general drafting room for engineering drawing below the senior year.

The room beneath the drafting room is used for bench work in wood, and contains no shafting or machinery of any kind, thus there is no trouble in the drafting room due to vibration.

This portion of the building is covered with a simple gable roof, giving no opportunity for overhead lighting.

The drafting room is 86 ft. 6 in. by 34 ft. 8 in. by 12 ft. 3 in. in height inside, and is lighted by side windows. The room runs east and west so that the prevailing light is from the north, the south wall being blank.

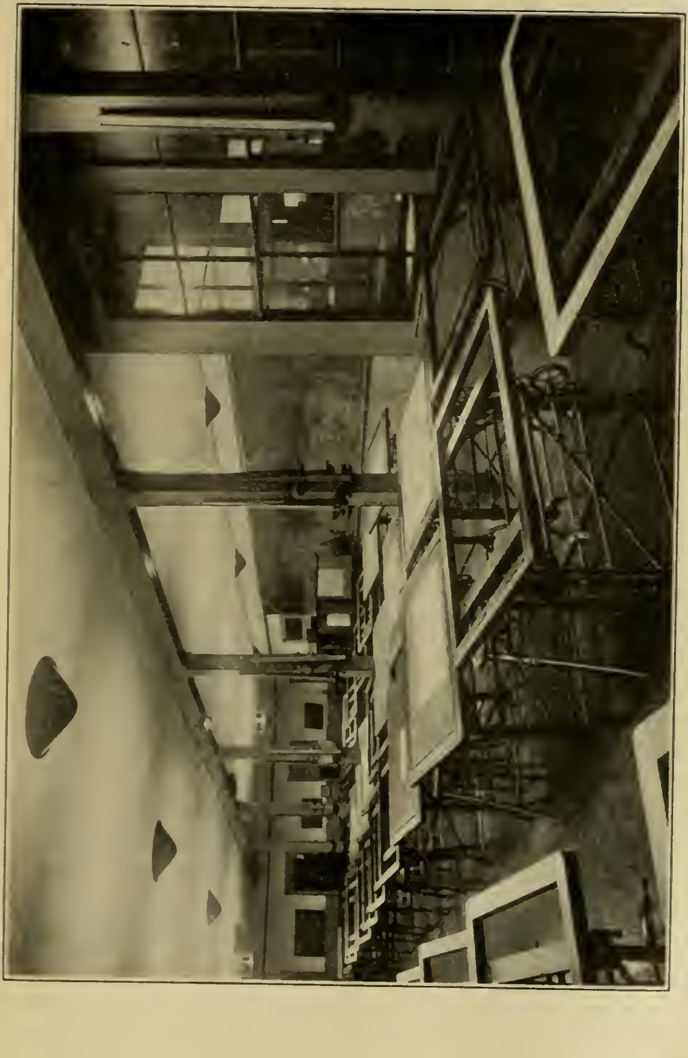
Considerable thought was expended on the painting and plastering of this room, and the following scheme has been carried out. All woodwork, including columns and beams, and a 5 foot wainscoting along the wall has been painted a light green (so light that it verges on the yellow). The balance of the walls and the ceiling, which were finished with a sandcoat of plaster, have been painted white with a water-paint. We have found that the daylight is very thoroughly diffused, and that students can work three or four hours at a stretch under ordinary conditions without any perceptible eye-strain, and that no artificial light is needed unless the day is especially cloudy excepting, of course, after 3:30 or 4:00 P. M. during the winter months.

From the first the attempt has been made to light this room by indirect means. Several schemes were used, in the first few of which we attempted to make use of commercial apparatus. The one that proved the most successful, under these conditions, was a combination of mercury tubes and incandescent arcs with opalescent reflectors. So much of the light however was absorbed by the reflectors, that we eventually designed and had constructed metal reflectors in the form of hyperboloids. These were used first with the incandescent arcs, but, within the past few months, we have taken out the arcs and put in 250 kw. tungsten lights. We have nine of these lights and are more than pleased with the results obtained. A photograph (see cut) taken in this drafting room at 9:30 at night shows an almost total absence of shadows at and above the level of the table tops.

All the metal-working shops are of one story construction, and the later ones have the saw tooth roof. The advantages, from the light standpoint, that may be obtained by the saw tooth construction are such that it is probable that this type of roof will be used on all our future shop and laboratory buildings.

The overhead drive, by means of shafting and belting, is maintained in the machine shop but is eliminated in so far as possible in the others.

The engineering laboratories, as stated by Professor White in his article, are in a building 200 by 113 feet with saw tooth roof construction and repeating bays 25 feet in width. The



PHOTOGRAPH OF GENERAL ENGINEERING DRAFTING ROOM, KANSAS STATE AGRICULTURAL COLLEGE.

Taken 9:30 p. m. January 27. Exposure 60 minutes. There is no indirect light in office (right hand corner). What is seen there is reflection of one of the others.

south bay is divided into a basement and two stories, the basement being used for locker rooms and for rooms for the preparation of cement and stone specimens. The first floor is used for offices and a reference library. The second floor, which extends over the next bay, is used for drafting rooms and offices. The natural lighting in the drafting rooms on this floor is secured through the saw tooth roof, and is such that no shadows are to be detected in any part of the room. So far, artificial lighting has not been found to be absolutely necessary, but there are certain times when it will be desirable and we are, at present, working on a scheme whereby we hope to secure the greatest possible diffusion through direct lighting.

This building faces south and it was possible to conceal the saw tooth construction from the south and east sides by simply giving a mansard effect, sloping from the top of the walls to the peak of the teeth. It would have been possible to have made this same construction on the west side, but as we anticipate adding to the building on the west, the saw tooth construction was carried to the wall.

The balance of the building is now divided into an amphitheater, equipped with opera chairs, and with a seating capacity of 130; a strength of materials laboratory one half of which has a head room of 33 feet 10 inches below the roof trusses; a room 75 by 133 feet containing thermodynamic and hydraulic laboratories. Included in the thermodynamics laboratories are the engines, turbines, and generators which supply power and light for the entire College.

The next room, which is 50 by 112 feet and is open from the basement floor to the roof, contains high pressure boilers and has provision for two 100-horse-power gas producers which are now installed just outside this building. This room is also a part of the thermodynamic laboratory, in that arrangements are made for thoroughly testing all appliances.

The gallery construction is maintained throughout the entire building except in the case of offices and drafting rooms. In the case of the thermodynamic laboratory the heavy machines are erected on foundations 10 feet above the basement floor line, and the first story floor constructed from foundation to foundation, on which rests some of the lighter machinery, the switchboard, etc. The object of this raising of the machines is to provide ample facilities for piping, condensers, etc., below the prime-movers.

The total floor space, at present, is 86,144 sq. ft., of which 2,400 sq. ft. are devoted to offices; 1,000 sq. ft. to reading rooms; 4,200 sq. ft. to lecture rooms; 3,600 sq. ft. to locker and toilet rooms; 26,300 sq. ft. to laboratories; 8,000 sq. ft. to drafting rooms; 22,000 sq. ft. to shops; 6,000 sq. ft. to laboratory galleries, and the balance divided among halls, storage rooms, blue print rooms, coal bins, etc.

ADDRESS OF WELCOME ON BEHALF OF THE UNIVERSITY OF PITTSBURGH.

BY CHANCELLOR SAMUEL BLACK McCORMICK,

Of the University.

Gentlemen of the Convention: I want to express for the faculty of our University and for myself our appreciation of the privilege of having you with us at this closing session of the meeting.* I trust that the Convention has realized fully your expectations.

We are trying to make this section of our industrial city a useful one from every point of view. You have been meeting in the splendid Technical School buildings of the Carnegie Institute. On the same axis exactly, and about the same distance as the Technical Schools from the Carnegie Institute, is the University of Pittsburgh, where you are now assembled, and which on February 28, 1912, will celebrate the one hundred and twenty-fifth year of its existence. Some of you have not thought of this institution as being so old. From 1787, the year of its incorporation, until 1819, it did simply the work of an academy. In 1819 the men who were managing its affairs secured a new charter providing for full university courses and transferring all the property of the academy to the new institution. The university has had, therefore, a continuous existence since February 28, 1787, first as an academy, then as a college and finally as a complete university. Dr. Bishop, the dean of our school of engineering, tells me that in 1846 this institution granted the first engineering degree, that of civil engineer. I have no doubt that the information is quite correct, for I know that about 1840 the university, then known as the Western University of

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* The closing session of the Convention was held in Thaw Hall, University of Pittsburgh.

Pennsylvania, began to expand and made an attempt to do regular university work. From that time through the great fire of 1845 up until the second fire, which destroyed the second building of the university in 1849, a fine law school was carried on. It was in these early days, therefore, that plans were made, never wholly abandoned, which some decades later resulted in the establishing of the engineering school of the university for the service of the community and to which the city is so well adapted.

Upon this new site, purchased only three years ago, we have several of the buildings already provided. The Twentieth Century Club, the Soldiers' Memorial Hall, the Armory, the University Club, the Athletic Club, the Forbes Field, the building of the Carnegie Institute, with the Technical School buildings are only the beginning of what will be here after a little. We are sorry that our campus is in such a state of confusion, but that we cannot help. Roadways over the forty-three acres which extend back over the hill are being constructed by the city of Pittsburgh, and we hope that they will be completed some time during the fall. Shortly we shall begin the erection of the dental building on the brow of the hill. The gymnasium is in process of erection just over the hill. From this point there is a very beautiful view of the park, and indeed over the entire eastern part of the city.

The work in which you are specially interested is one in which we are deeply concerned in this great industrial center. Dr. Bishop has a paper describing the co-operative plan which we have adopted at the University of Pittsburgh. I notice that Dr. Raymond, whom you have elected President of your association, refers to a plan which he announced several years ago, of a four-term or all-year-round course. That is also a part of our plan, so that the University of Pittsburgh joins the number of schools to which Dr. Raymond refers as carrying on the work during practically the entire year.

Now I have said these things very informally, but I want you to feel that, just as you have been at home the other two days of your meeting, so I want you to feel perfectly at home in the university here this morning. The University of Pittsburgh, through myself and through the members of our faculty who are in attendance, gives you a most hearty welcome. We trust that you have made genuine progress in your conference in Pittsburgh, that your problems are nearer solution than they were when you came together, and that your memories of our city and of its institutions of learning will ever remain vivid and delightful.

RESPONSE ON BEHALF OF THE SOCIETY.

BY WM. KENT,

Vice-President of the Society.

Chancellor McCormick and gentlemen: We are overwhelmed in our appreciation of what has been done for us in Pittsburgh. A philosopher has defined gratitude as "a lively sense of favors to come." Therefore, to show that we are really appreciative of the honors, I am going to give you a hint that you want to invite the Society back here again about ten years from now.

In this wonderful section of this modern Athens, this Acropolis, you have already shown that you know how to get some of the foundations of culture; that is, immense buildings, good architects, beautiful scenery, plenty of money. When we come back about ten years from now we will probably find this Acropolis with more beautiful buildings of masonry; and I am looking forward to the time when this modern Athens will be famous as was the Athens of old, not only for buildings and sculpture, but for men. The fame of Greece was the fame of men, not of mere masonry; and the Society for the Promotion of Engineering Education has one big problem ahead of it which today we do not know how to solve—how to discover the best men, and how to find the particular methods that these men shall adopt to instill into the minds of youth what ought to be put there. There is the great problem of education of the future; and I hope that the people of Pittsburgh will take up that problem, and that when we come back here ten years from now you will say, "Here is our product. Here are our methods. Here are our men." You have magnificent buildings, you already have obtained famous men; and we hope ten years from now, you will point with still greater pride to your products.

AN ENGINEERING COURSE FOR UNDER-CLASSMEN.

BY W. A. HILLEBRAND AND S. B. CHARTERS, JR.,
Department of Electrical Engineering, Stanford University.

It is standard practice in American technical schools today to confine instruction in electrical engineering to the last two years of the course. This custom, backed as it may be by good and sufficient reason, has for the student who enters college with the intention of becoming an electrical engineer, two serious drawbacks.

In the first place, the young man must wait two years at least before learning anything about that which he has determined shall be his life work, and three years or more elapse before he is able to judge, even from what experience college can give him, whether his choice was a wise one. Whatever enthusiasm he may bring with him as a freshman often suffers from the severe regimen of science and mathematics on the one hand and an intense social life on the other, through which he wanders with more or less purpose according to the dictates of temperament, previous training and immediate environment.

A second disadvantage lies in the fact that the faculty in electrical engineering, the men with whom he will be most intimately associated during his college course, who will have his welfare more closely at heart, who will feel their responsibility toward him more deeply, who will have the greater interest in his ultimate success, and who should, therefore, have the greatest influence over him, do not make his acquaintance until his college career is often more than half over. Valuable time is thereby lost in gaining headway, before the personality of this portion of teaching staff can exert its proper influence.

With these ideas in mind, a course, conducted by the faculty of electrical engineering, was this year instituted at Stanford University for the freshmen who register in that department.

Our purpose was primarily to get acquainted with the first-year men, their needs, and, if possible their aspirations, and in return to stimulate in them a professional interest based on a study or contemplation of concrete engineering achievement. We have also attempted to give them an idea of the real conditions of industrial life and to make them understand why they came to college, what the college may be expected to do for them, and above all else what it cannot possibly do. In pursuit of this ambitious purpose, with but one hour at our disposal, the following program was adopted.

As a preliminary, answers were required from each man to the following set of questions. A summary of the replies with some of the conclusions drawn therefrom will be given later.

General Information for Department.

1. Age?
2. From what town do you register?
3. Father's occupation?
4. Are you self-supporting, wholly or in part?
5. Have you ever worked at any gainful occupation of any kind? If so, enumerate the various kinds of employment and state about how long, all told, you were occupied at each.
6. Where did you go to school?
7. What were the principal courses studied?
8. In what things of life, of any sort, are you particularly interested?
9. Have you studied electricity and magnetism in physics?
10. What is your idea of the duties of an electrical engineer?
11. Is there any particular line of work toward which you are looking after graduation and for which you expect the college to fit you?
12. Name all the distinct branches of electrical engineering that you can think of.
13. Does any one of these appeal to you more than another? If so, name it and tell why.

14. What is your reason for coming to Stanford rather than to another college?

15. What is your conception of the purpose of an engineering education?

16. About what proportion of your college work will be devoted to the study of purely electrical subjects and why?

17. What has question 16 to do with your life work?

The course itself, entitled "A Survey of Electrical Industries," is divided into two parts, lectures, occurring every two weeks, and interviews once a month with each student, covering assigned reading. In addition thereto a written report is required on each lecture. The three members of the faculty co-operate in the work of instruction, each giving the lectures appropriate to his particular field and having one third of the class report to him for the monthly interview. One hour credit per semester is allowed.

In assigning topics for outside reading each student was asked to signify some branch of engineering activity about which he had a curiosity to know more, and was then referred to appropriate articles in the periodical literature. The idea was to stimulate his interest by giving him something concrete, definite, from which general principles might be derived if need be. A constant effort was made to impress each individual with the fact that much useful and valuable knowledge may be acquired without waiting until the middle of the senior year, provided he will use his initiative and avail himself of the opportunity presented.

A provisional schedule of lectures covering about three semesters is submitted herewith:

1. Power sources, engines, turbines, gas engines.
2. Water wheels.
3. Dynamos, motors, et cetera.
4. Markets, transmissions and distributions.
5. Transmission network.
6. Electric street railways.
7. Electric lights.
8. Telephones.

9. Telegraphs.
10. Lighting.
11. Wireless transmission.
12. Electrochemistry.
13. Electric furnaces.
14. Railways.
15. Industrial power.
16. Lighting sources.
17. Illumination, photometry, and principles thereof.
18. High tension networks.
19. Trend of progress.
20. Ditto.
21. Ditto.
22. Historical.
23. Biographical.
24. Societies and Bureau of Standards.

They are strictly "informational," intended to give some understanding of the various applications of electricity to the uses of everyday life. The first part of the year, however, was devoted to the following topics: reasons for coming to college, and what may be expected from a college course; the standard four-year course for electrical engineers, covering the reasons why the various subjects occupy the places they do and the importance of mathematics as prerequisite for the more advanced subjects; the importance and value of a careful use of English; the education of a broad-minded citizen; professional ethics.

So much by way of explanation. Now, what of the results after six months of operation?

A summary of the replies to the more important questions submitted develops the following facts:

Number of replies: 25.

Average age: nearly twenty years.

Geographical distribution: from the eleven Pacific Coast states, 19; from Rocky Mountain states and west thereof, 22; scattering, Missouri, Kentucky, Michigan, 3.

Number self-supporting: wholly, 4; in part, 5.

Employment: Twenty-one have worked at some gainful occupation; average of total time, per man employed, 17 months; average for class, 14 months.

Home environment: The fathers of nine of the men are engaged in occupations that may in any way be described as mechanical. These are: locomotive engineer, mining engineers (2), manufacturers (2), sheet metal workers, manager of telephone and hydro-electric companies (one each), contractor and builder. The other occupations run: real estate dealer, teacher, farmer, grocer, banker, mariner, barber, judge and lumberman. The largest single group are farmers.

The replies to question ten show almost without exception that to these freshmen an electrical engineer is a man directly associated with the design, construction or operation of electrical machinery. Of the great co-operative enterprise for accomplishing results, of which engineering from their narrow viewpoint is but a tool, or of the various economic factors with which their lives will be largely taken up, they have no conception. This is, perhaps, only natural, but a point of view which it is none the less important for the teacher to ascertain.

Concerning the magnitude of salaries commonly paid to men in the profession there is also an exaggerated belief. For instance, two of the men who reported to the author, after reading Damon's article on the ''Opportunities in the Electrical Business,'' were very much disturbed in mind as to whether they had made the proper choice of a vocation.

Another conclusion to which we have come through our acquaintance with these young men, is that most of them firmly believe the possession of an engineering degree will of itself place the holder on the road to success and a large salary, and that at a date not very remote from graduation. They are only too ready to admit that for the first few years it will be hard work with low pay, but are firmly convinced that, once embarked upon the road, industry will bring its full reward.

Taken in connection with the geographical distribution of our students, a careful analysis of the replies to question fourteen convinces us that if a man selects his college or university because of popular impression or from what he is able to learn of the excellence of its course in electrical engineering, he goes to any place but Stanford. Most of our men frankly said they came to this university because it is "near." That is, we draw from among a restricted clientele students who come to college because the opportunity is offered, and who take electrical engineering because, of various ways of earning a living, they think that will be both congenial and profitable. This is not intended in any way as a reflection upon our student body, who will average as high as the students at any other institution, but it does mean that any institution which expects to meet efficiently its particular problem must begin by squarely facing the underlying facts. For instance, under conditions such as these, are the responsibilities of the teaching staff the same or would the same type of instruction be offered as would be the case if every student spent his undergraduate days at several different universities, taking from each the best it had to offer in his line?

What has been said about Stanford in regard to the geographical distribution of its students will be found true of most of the universities of this country, in spite of a possibly wider reputation.

The reaction of such a group of students to the course we are attempting to give is about what might have been expected. Especially is this true of their attitude toward that portion designed to stimulate initiative and independent observation. To most of them it makes no appeal and is handled like any other prescribed subject, with results that are a distinct disappointment. This attitude of mind, mental lethargy, if you will, pervades all classes of our students, to such an extent, for instance, that we have been unable to interest even the seniors in the meetings of the San Francisco section of the American Institute of Electrical Engineers, a journey of thirty-five miles and some small expense being unable to compete with the social possibilities of Friday night.

The necessity of combating such a spirit was the prime reason for instituting this course, in the hope that by starting early enough and applying the pressure throughout four years instead of a year and a half, results might be achieved. Out of the twenty-five men there stand perhaps five alert, ambitious lads, whose reaction is in every way satisfactory and who will, by their senior year, rise head and shoulders above their comrades. Through the potent influence of such men over their fellows we hope, in the course of years, to develop a greater appreciation of the necessity for each man doing more for himself during his college course than is required for graduation.

It is interesting to note that these same men were the first to respond to our urgent admonition to do shop or field work during at least a part of the summer vacation.

Upon the faculty in electrical engineering our acquaintance with these freshmen has had a profound influence, chiefly in revealing to us more clearly the broader aspect of our problem, wider responsibilities toward the students who come to us from a world hypnotized by the magic of mechanical achievement, and the possibilities that arise through a more intimate contact with our men through a period of four years instead of one and a half or two. For example, one of our most indifferent students wants to be an electrical engineer simply because, having clerked in a store, a distasteful occupation, and possessing no taste for the humanities, he sees no other course open to him. We consider it a distinct advantage to have "spotted" such a man in his freshman year, for there are not a few of his kind who escape the dragnet of calculus and descriptive geometry.

An interesting side light, but of vital significance to the educator, is the fact, which we discovered with quite a shock, that these freshmen are in many respects quite as mature as our seniors. If it be true that a man has attained his mental growth by his twentieth year, then it is of vital importance that teacher and parent alike appreciate the true functions of school and college training and the part which each can effectively play in the development of a man.

To quote Mr. Flexner on this point: "As a matter of fact, the early years are of the most vital consequence to an education that proposes the exploitation of the individual on native lines."*

Chiefly because of its value to ourselves in revealing our duties more clearly, we feel, with an optimism which it is hoped time will justify, that this course for the Underclassmen is the most important step we have taken since the present personnel composed the staff of electrical engineering at Stanford University.

DISCUSSION.

Chairman Kent: The paper is now open for discussion. I think we all agree that one of the most important things that we can do in engineering education today is to try to influence our students; and we are glad to know that Stanford University is making an attempt to learn something new in the mental constitution of the student to see if we cannot find a better way of improving him than we have followed in the past.

Dean M. E. Wadsworth: In the school of mines of the University of Pittsburgh we start with our students upon entrance by giving them instruction in geology and mining, besides the other necessary studies. We do this because long experience has taught me that the average student does not wake up until he has reached the sophomore or junior year. He does not realize what he is studying. My idea here is to put the men immediately into contact with the things they are going to be in contact with in their future life. I feel, also, that if we force a man into the study of English when he has no interest in it whatsoever, he will know no more when he gets through than when he begins. But if we teach him so that he knows he must have his English, as he must have the other subjects, then his interest and enthusiasm is excited and he will learn more in one term than he will in five years of the ordinary forced work. Our practice is to differentiate between two classes of students, those who expect to be managers and those who wish to be engineers. The bachelor of science is not required to take any more mathematics than he wishes other than simply trigonometry and surveying. Then he devotes his time to the things that will be necessary for him as manager of mines. The engineer, however, is required to take all of the engineering work that is taken in the average school, before the differentiation begins. I mention these matters because many of the suggestions that have been made by the speakers at these meetings have been tried here and at the schools of mines in Michigan and in Pennsylvania. If they prove right we shall continue them. It is a question of experimenting.

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* "The American College," by Abraham Flexner, p. 66.

Director J. F. Hayford (by letter): It seems to me that this paper describes a move in the right direction. It is of prime importance for a man at every period in his life to see the bearing of his own activity upon other activities, to understand his relation to other men. The course outlined in the paper seems well adapted to help the student in this way, to tend to make him see the relations between his college training and his later life. It is interesting to note that the authors have found that this course gives them, the teachers, a clearer view of their relations to the students.

While reading the paper I had a curiosity, which was not satisfied, to know the attitude of the authors toward "the intense social life" of the student, referred to in their second paragraph and again later where it is indicated that "the social possibilities of a Friday night" appealed more strongly to the student than an unusual opportunity to get into touch with engineers and engineering. Sociability should be a flavor, with tonic properties, running through all parts of a man's life or the life of a student, through his work as well as his play, through his study hours as well as his leisure hours. Too often, parents as well as students seem to believe that sociability in college life is a thing apart, something to be cultivated by long hours spent in fraternities, in parties and in various so-called college activities which are carried on as a rule outside of a scholarly atmosphere. Such alleged sociability may be and often is a vocation rather than an attitude towards one's fellows, largely a waste of time rather than the source of inspiration which true sociability in college and in life may be, and is to some men. Do we not owe it to our students to make greater efforts to guide them toward true sociability and away from waste of time in the name of sociability? If we succeeded better in such efforts would we not thereby indirectly raise the standard of true scholarship among our students?

The authors have prepared an important paper in regard to this new course at Stanford at a time when the course has been given for less than a year. A still more valuable paper should be contributed by them to the PROCEEDINGS of the Society on this same topic when the course has been given for four years, when the present freshmen are graduating.

ELECTRICAL ENGINEERING INSTRUCTION.

BY ELLERY B. PAINE,

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The writer will endeavor in this paper to tell how the problems of electrical engineering instruction have been solved at the University of Illinois. Here, as in all institutions, there is the problem of what to teach of the ever increasing volume of subject matter. There is also the problem of how to handle large and growing classes. This paper will be limited to a discussion of the instruction given by the department of electrical engineering to the undergraduate electrical engineering students. Some students from other departments are also given this instruction. The briefer courses in electrical engineering intended for students in other departments of the university will not be included in this discussion. It will be seen that electrical engineering instruction at the University of Illinois deals largely with the theory of electrical apparatus. But descriptive instruction is given sufficient to familiarize the student with the construction and operation of electrical machinery. The student is first given a brief general survey of the field of electrical engineering and then proceeds to a study of details. Continual repetition of important principles is given until the student has had opportunity to master them. Knowledge of mathematics is considered of highest importance. The time devoted to the study of mathematics has been increased. The tendency is to introduce more and more problems in electrical engineering requiring differential equations for their solution. At the University of Illinois all students in electrical engineering follow the same course of studies. There are no undergraduate electives offered. The instruction in electrical engineering extends throughout the junior and senior years.

Outline of the Courses.

Class-Room.—During the first semester of the junior year the students meet for class-room instruction three times a week. The remaining three semesters they meet for class-room instruction four times a week. For class-room instruction the electrical engineering students are divided into four junior sections and four senior sections. This makes about twenty students in each junior section and fifteen in each senior section. Class-room instruction is in charge of two instructors, each of whom is responsible for two junior and two senior sections. During the first semester of the junior year each instructor meets his two junior sections combined for a lecture once a week, and each section singly for recitations twice a week. For the remainder of the course he meets his sections combined for a lecture twice a week and singly for recitations twice a week. The class-room instruction, after the first semester of the junior year, does not follow a text-book closely. The student provides himself with several books of permanent value for use as reference books. The principles studied are developed in lectures. Daily problems for home solution are given. A large per cent. of these problems require numerical calculation and involve the plotting of results in curves. Lectures and recitations alternate. The method of conducting the recitations varies with the subject. Written recitations are held frequently. In the recitations the students are questioned regarding the subjects taken up in the lectures and also about the results of their problems.

Laboratory.—Each student spends one three-hour period in the electrical engineering laboratory each week of the junior and senior years. The laboratory equipment is such that it is not advisable to allow more than twelve to sixteen students in a laboratory section. It is possible to have one junior section and one senior section working simultaneously. The students in each laboratory section are divided into squads of three or four. The students forming a squad work together in their tests. Each week in turn one of the students acts as leader of his squad. The leader directs the experimental work and is held responsible for all instruments and apparatus used. The machines are not permanently connected with the switchboard. The students for each test must make their own connections. In general the students are left to their own resources as much as possible. Each student must prepare a carefully worked out report of each experiment. In this report he is expected to answer questions printed in the directions for making the experiment. Special blank forms are not used.

Design.—Instruction in electrical engineering design is given throughout the senior year. Each week of the first semester the student attends one design lecture and spends one three-hour period in the design-room. Each week of the second semester he attends two design lectures and spends one three-hour period in the design-room. Electrical design is taught by two instructors, each of whom is responsible for about half of the students. Each instructor meets all of his students at one time for lectures. His students are divided into sections of about twelve for design-room work. The design-room work is distinctly calculation rather than drafting. No drawings are made except such sketches as are necessary to obtain measurements needed for calculations. The work in design follows closely the instruction given in class-room.

Seminar.—The senior electrical engineering students meet once each week for a two-hour seminar period. The students in turn present papers on some subject they have chosen after consultation with the instructor in charge. A large proportion of the papers consist of description of some phases of engineering construction or operation with which the students have had practical experience. After the paper is presented the subject is open for discussion, which often is animated. The student who presents the paper is expected to answer all questions or objections, and since he naturally wishes to be able to hold his own, he has a strong incentive to master his subject thoroughly. Several lecture series are given by instructors on such subjects as illumination, telephony, electric railway motors, etc.

Thesis.—Thesis subjects are assigned the first semester of the senior year. The student is supposed to do preliminary work the first semester, but the real task of thesis preparation is carried out the second semester. The students work singly or in groups according to the nature of the subject. Each thesis is under the supervision of an instructor, to whom frequent reports of progress are made.

Inspection Trip.—In October or November the senior electrical engineering students are given a carefully planned inspection trip. The time devoted to this inspection is usually three days. Under the conditions at Illinois it is believed a trip of this length yields the maximum benefit with the minimum expense of time and money.

Correlation of the Courses.

The end in view is to make the combined courses a unit, and not necessarily to make each individual course complete in itself. To accomplish this aim it is important to provide as perfect correlation as possible. The more important principles are presented from different view points in class-room, laboratory, design-room and seminar. This method emphasizes what is most important and leads the student to a more accurate understanding of the subjects so presented. The table shows the subjects taken up each semester.

Description of the Courses.

Junior Year, First Semester.—The class-room instruction follows a text-book closely. Much emphasis is placed on the fundamental laws which are the basis of electrical engineering, and considerable time is devoted to descriptive teaching concerning the construction and operation of the more common pieces of direct and alternating current apparatus. The student is given thorough drill in the solution of simple direct current problems. Dynamo models and parts of machines are used as an aid in teaching construction details. Demonstration lecture experiments are performed before the class as an aid in the study of the operation of direct current generators and motors. Problems are assigned based on data obtained in the lecture experiments. When feasible, class-room experiments are made at a later date to show the students how closely their calculated results compare with the actual quantities. In the study of magnetic circuits the student makes

Semester.	Class-room.	Laboratory.	Design-room.
Junior year. First.	Fundamental laws. Electric circuits. Construction of D.C. & A.C. apparatus. Operation of D.C. generators. Operation of D.C. motors. Magnetic circuits. Storage batteries.	Study of D.C. circuits. Operation of generators and motors. Characteristic curves of various types of motors and generators.	
Junior year. Second.	A.C. wave forms. Vectors. Complex quantities. A.C. circuits. Transmission lines. Transformers.	Study of D.C. generators and motors. Determination of wave forms. Study of A.C. circuits. Measurement of power. Study of artificial transmission line.	
Senior year. First.	Transformers. Wave analysis. Three-phase circuits. A.C. generators.	Transformers. Poly-phase power measurements. A.C. generator tests. Parallel operation of D.C. generators and A.C. generators. Photometric tests.	Transformer. D.C. generator. Alternator.
Senior year. Second.	Synchronous motor. Induction motor. Distributed inductance and capacity. Synchronous converter. Transient phenomena. Commutator motors.	Storage battery. Synchronous motor. Three-phase transformers. Induction motors. Synchronous converter. Arc lamps. Integrating wattmeter.	Alternator. Induction motor. Electric power plants. Illumination. Electric drives. Systems of distribution. Synchronous converter.

calculations for several problems, including that of finding the saturation curve of a direct current generator from the dimensions of the machine. A few lessons are given to a brief study of storage batteries.

The experiments performed by each student in the electrical engineering laboratory the first semester of the junior year include the following:

Study of series circuit.
Study of series and parallel circuit.
Measurement of resistance by fall of potential.
Variation of resistance with temperature.
Starting and reversal of motors.
Static torque test of motor.
Brake test of shunt motor.
Brake test of series motor.
Magnetization curve of generator.
Characteristic curves of shunt generator.
Characteristic curves of compound generator.
Stray power test of a motor.
Speed control of motor by field rheostat.
Speed control of motor by armature rheostat.

Junior Year, Second Semester.—In the class-room the lessons for the first few weeks deal with the subject of alternating wave forms of voltage and current. The subject is developed by lectures and graphical problems. The student determines the instantaneous values of voltage generated in a coil which is assumed to rotate in magnetic fields of uniform and also non-uniform distribution, and plots these values to rectangular coördinates. In these problems the magnetic flux is represented by lines drawn on paper, and the voltage at any instant is taken as proportional to the rate of change of lines enclosed by the coil. The influence of magnetic distribution on wave shape is clearly brought out by these problems. The student learns the effect on wave form of distributing the winding by finding the voltage wave for the case of two or more coils in series with phase displacement of ten or fifteen degrees. The approximate wave form of an alternator with chamfered pole tips is found by the student. A projection oscillograph constructed by students is available, by means of which wave forms of voltage and current may be shown on the lecture-room screen. The student then considers the relation between voltage and current in a circuit containing resistance only. He is asked to determine the relation between current and voltage in a circuit containing resistance and also containing a coil. From his knowledge of fundamental laws the student is able to determine the influence of self-inductive reactance for any wave form of current, assuming constant reluctance for the magnetic circuit of the coil. In a similar manner he is led to work out for himself the influence of capacity reactance. The graphical problems performed and the wave forms plotted aid in making clear the meaning of the terms used, such as phase relation, cycle, etc. The distinction between effective and average values is discussed, and the student finds the relation between maximum, effective and average values for several of the wave forms represented in his problems. The subject of electric power in single-phase circuits is studied by assuming sine waves of voltage and current and plotting the power wave. The students assume various phase relations of voltage and current and learn not only that electric power is of double frequency but the relation between voltage, current, phase-angle and power. The student also solves a similar problem with a balanced two-phase circuit and discovers for himself that the total power is constant.

The differential equations for a circuit containing resistance, inductance and capacity are developed and the student obtains the solution for the case of a sine wave of current. The student finds this solution corroborates his graphical solutions. He also learns the numerical relation between reactance and inductance or capacity. The various methods of representing alternating vectors are studied. The method adopted for use is that of the polar time diagram. Steinmetz's symbolic method of calculation is taken up. To afford practice in the use of this system, also to make the student's understanding of circuits more complete many problems dealing with series and parallel circuits are assigned. Vector diagrams for all problems are drawn by the student in order that he may learn the connection between the algebraic expressions and the geometric representations of the same. As an example of alternating current curcuit the transmission line is studied in detail, and many numerical problems are given. The student is taught to arrange his numerical work in tabular form, also never to depend on a single calculation but to carry out the result for several cases with slightly varying conditions. These results should plot in a smooth curve if there is no numerical error in any of the calculations. The student also becomes familiar with the per cent. method, which he finds of great advantage. In this method full load voltage and full load current are taken as unity or one hundred per cent. The value of resistance or reactance is taken as the per cent. of full load voltage required to pass full load current through the resistance or reactance. These per cent. values are used in the calculations in place of the values of volts, amperes and ohms.

The transformer is easily understood by the student after his study of self induction. Lecture experiments are performed to illustrate the law of ratio of turns, the phenomenon of magnetic leakage, the influence of joints in magnetic circuit on core loss, magnetizing current, and magnetic leakage. The question of reactance is discussed, and by experiments the influence of relative position of coils on reactance is shown. The method of representing a transformer by an equivalent circuit containing resistance and inductance is developed. From the transformer constants derived from the lecture experiments the students make calculations to determine the influence of secondary load and power-factor on the transformer efficiency and regulation.

The experiments performed in the electrical engineering laboratory the second semester of the junior year arc as follows:

Compounding of shunt generator from magnetization curve and external characteristic.
Armature characteristic of shunt generator.
Magnetic distribution in air gap.
Rating of motor for measurement of power.
Determination of wave form by Mershon's method.
Determination of wave of magnetic flux.
Study of series circuit containing resistance and inductance.
Study of parellel circuit containing resistance and inductance.
Value of current and phase-angle in a circuit of varying inductance.
Value of current and phase-angle in a circuit of varying frequency.
Effect of frequency on indication of ammeter.
Measurement of power in single-phase circuit by wattmeter.
Study of artificial transmission line.

Senior Year, First Semester.—In the class-room a brief review is made of the ground covered in the preceding semester. Transformer operation is studied by means of curves showing the instantaneous values of voltage, current and flux plotted to rectangular co-ordinates. The student is given data for the hysteresis loop of a transformer and finds the flux and current waves assuming a sine wave of voltage. He also finds the flux and voltage waves assuming a sine wave of current. The student is taught how to analyze waves, and he finds the harmonics present in his waves of transformer exciting current and voltage. A series of problems is assigned to determine the relative importance, as regards efficiency and regulation, of the four transformer constants: core loss current, magnetizing current, resistance and reactance. Values of constants for a good transformer are given. Each student considers three of these constants fixed and calculates, for some particular load power factor, the efficiency and regulation of the transformer with a wide range in value of the fourth constant. Results are given out by students in class and are plotted in curves on the black-board. This method has the advantage of lessening the tendency of students to copy the work of others, and also affords interesting and valuable material for class-room discussions. The methods of measuring three-phase power are studied. The question of harmonics in three-phase systems is discussed. The influence of harmonics on three-phase transformer operation is investigated. A study of the alternator is then made in the class-room. The alternator vector diagram is drawn and equations for the calculation by complex quantities are developed. The student learns how to calculate the reactance of alternators. The relative magnitudes of reactance to be used for energy and for wattless current is discussed. The student learns how to calculate the armature reaction for machines with and also without definite poles. A group of problems is assigned, the solution of which shows the class the influence on the operation of an alternator, of changes in the proportions of the teeth and changes in length of air gap.

The experiments performed by each student in the electrical engineering laboratory the first semester of the senior year are as follows:

Methods of connecting coils of single transformer.

Reactance of a coil containing iron in its magnetic circuit with various values of current.

Determination of reactance drop of a transformer under load.

Efficiency of a transformer by stray power method.

Calculation of regulation of a transformer from no load readings.

Determination of hysteresis loop of a transformer.

Measurement of poly-phase power by one, two and three wattmeter method.

Ratios of voltages and currents in Δ and Y-connected transformers.

Separation of iron losses of a transformer.

Determination of Steinmetz's coefficient and exponent.
Characteristics of incandescent lamps.
Determination of distribution curves of incandescent lamps.
Measurement of D.C. and A.C. arc lamps by reading illuminometer.
Open circuit saturation curve of an alternator.
Synchronous impedance of an alternator.
Parallel operation and load division of shunt and compound D.C. generators.
Parallel operation and load division of alternators.

In electrical engineering design the first semester of the senior year the time is devoted entirely to a study of the design of electrical machines. In the lectures the methods of design are taken up. The student makes calculations for the following:

Design of a transformer, single-phase and poly-phase.
Design of a direct current generator.
Design of an alternating current generator (started).

Senior Year, Second Semester.—In the class-room the vector diagram for the synchronous motor is developed and equations derived for the calculation by complex quantities. Constants for a synchronous motor are given and the student calculates its characteristic curves. Problems are assigned which show the influence of varying loads on synchronous motor stability. The students make calculations which show the use of the synchronous motor in voltage control of distributing systems.

The induction motor is studied in a similar way and the students solve a carefully planned series of problems. These calculations make it possible to bring out clearly the important features of induction motors.

A few lessons in mathematics are given to review the differential equations which appear frequently in engineering problems. The students make calculations of long distance transmission lines, assuming distributed inductance and capacity.

They also solve several problems involving the transient phenomena of starting or stopping currents.

The synchronous converter is discussed. Several problems are assigned involving the calculation of voltage, current and heating ratios of synchronous converters.

The theory of commutator alternating current motors is developed and each student calculates from assigned data the characteristic curves of a series alternating current motor.

During this semester frequent written quizes are held covering all the student has studied in electrical engineering.

The experiments performed by each student in the electrical engineering laboratory the second semester of the senior year are as follows:

Storage battery test.
Operation of synchronous motor under variable load with constant field excitation.
Phase characteristics of synchronous motor.
Determination of wave form by an oscillograph.
Study of harmonics in three single transformers, three-phase connection.
Study of harmonics in core and in shell type three-phase transformers.
Study of A.C. arc lamps.
Brake test of an induction motor.
Stray power test of, and circle diagram for an induction motor.
Efficiency of an alternator by stray power method.
Study of induction type integrating wattmeter.
Starting and operation of a synchronous converter.

In electrical engineering design for the second semester of the senior year the time is devoted partly to the calculation of machines and partly to a study of power plant design. The work done by the student during the design-room periods includes the following:

Design of an alternator (started in first semester).
Design of an induction motor.
Design of a synchronous converter.

Power plant design is taken up in the lecture periods. The problem assigned this year was a power plant for the local city. The city was divided into sections, and each student made a careful survey of one section and estimated the amount of electric power used in that section for house lighting, street lighting and power. From these estimates the load center was determined, also the estimated load curve of the station. The students were interested to find the actual load curve of the existing station differed by about ten per cent. from the estimated load curve. The best location for the plant was studied and the value of land for the different locations obtained. The size and number of generating units was discussed. Each student then made plans for the station lay-out and estimated the probable cost of the same.

The other subjects discussed in the design lectures include the following:

Water power development.
Interior and street lighting.
The application of electricity to machine driving.
Systems of electric distribution.

The student is assigned problems in each of these subjects.

The results obtained by this system of instruction have been excellent. The students are enthusiastic and show great interest in their work. One indication of this is the fact that the average attendance is found to be about ninety-eight per cent. of the number enrolled. The department believes that the mastery of the symbolic method of calculation gained by this system of instruction enables the student to get an understanding of electrical engineering theory that would be impossible otherwise. The daily solution of numerical problems gives the student valuable training in the habits of accuracy and also leads to a better understanding of underlying principles. The department is of the opinion that from the administrative point of view there is greater advantage in having all the electrical engineering students follow the same course of instruction than in having them break up into several more highly specialized courses. Since the student usually can not be sure in which part of the field of engineering his opportunity will open, it seems better for him to get a thorough grounding in the general principles of electrical engineering than to specialize too fully in his undergraduate years. At the University of Illinois the graduate student in electrical engineering has abundant opportunity to pursue advanced studies dealing with any phase of the electrical engineering field in which he may choose to specialize.

Discussion.

Professor C. Francis Harding (by letter): The writer of the above paper is to be congratulated upon his logical and concise outline of the course in electrical engineering administered at the University of Illinois. The paper sets forth very clearly in a few words the policy underlying the administration of the electrical engineering work as well as the detailed contents of the course during the junior and senior years in which the students are largely engaged in work under the direction of the department of electrical engineering.

As the course outlined by Professor Paine is quite similar to that administered by the university with which the writer is connected there seem to be but two questions of prime importance in the paper which warrant further discussion. These questions are:

1. The advisability of departing so radically from the use of the text-book and thereby requiring a relatively large proportion of lecture work.
2. The advisability of the working of a large number of problems by the students at home.

Discussing the above problems in order, although the extent to which text-books are used or list of texts used do not appear in the above paper, it is the understanding of the writer from other sources and the natural inference from the above paper that text-books are used less for daily assignments in the course outlined above than in the average technical university, thereby requiring of necessity a larger proportional amount of lecture work.

While the writer believes thoroughly in the necessity of lectures and while it is practically impossible to apply successfully any text-book to a course in electrical engineering, no matter how complete and well written that text-book may be, unless the book is written by the instructor who administers the work for the particular course with which it is to be used, yet it is believed that it is quite possible to go to the other extreme of confusing the student with a maze of references to books not in his possession and a set of lecture notes which cannot be made sufficiently complete and accurate for efficient use in later years. Those of us who have had occasion to work out original problems based upon fundamental theory, which we have not reviewed for some years perhaps, find ourselves involuntarily turning back to the well-remembered worn page of the text-book we studied as an under-graduate in order to clarify in our own minds the particular theory involved from the viewpoint which we grasped so thoroughly at that time and which thereby becomes the proper and most efficient viewpoint upon which to base our further developments of the theory. In short, it is the belief of the writer that no amount of lecture work and references can entirely make up for a definite assignment in the best text available, which text is owned by the student and will be used in the future as a most useful and efficient reference. The lectures, references and outside problems should. therefore, in the belief of the writer, augment and further clarify the text and be so chosen as to adapt the text to the particular needs of a particular class of students, but great care should be taken not to permit such features to crowd the text out of daily use in the class room.

No instructor can be a stronger advocate than the writer of the absolute necessity of a large number of problems so planned as to augment the text-book work in a given subject and to give the student a clear idea of the application of the theory to practice. In fact, it is believed that the problems should go one step further and involve wherever possible the financial considerations of the problem, for the technical student, especially in classes under the direction of an academic instructor who, not having had actual practice in the engineering field, is very apt to emphasize small gains in efficiency and operating characteristics of machines and circuits at the expense of high cost of construction, installation, operation and depreciation. It is the belief of the writer that technical graduates in general are not taught to consider sufficiently the effect of the ''almighty dollar'' upon engineering problems. This fact is appreciated by the executive under whom the technical graduate serves immediately after graduation and is one of the important experiences which must be obtained before any degree of responsibility can be undertaken.

However, in spite of this feeling with regard to the necessity of problems, the administration of problem work in the course of electrical engineering has to be given careful attention. In the outline in the above paper it will be noted that a large number of problems are worked out by the students at home. No means has yet been found by the writer of assuring the instructor that the student has done a sufficient amount of individual work upon such a problem to thoroughly acquaint him with the principle involved therein. Tests may be administered to cover the work but they cannot be given sufficiently often nor even daily recitations made sufficiently complete, especially with large classes, to guarantee to the instructor that even the important principles involved in the outside problem have been thoroughly grasped by all students. Problems worked out in error with the errors left uncorrected or problems worked out by others and copied by the students and handed in as their own work are worse than useless for they lead the student to believe either that he understands the problem when he does not or that he can succeed in future engineering undertakings by deceiving his superiors.

The writer grants that it is difficult to strike a happy mean between the two extremes of too few illustrative problems and too many problems involving outside work and he also grants that there are many problems which are necessarily too long to be worked out in a single recitation period. Necessarily too long, I say, because of the fact that a large number of disconnected steps in the development of a result taken as individual problems and not united into a whole do not in many cases satisfactorily bring out the point desired or give the necessary training to the student for such work as the preparation of engineering reports and estimates for instance. However, with the administration of calculating periods in connection with laboratory work and design, involving detailed concrete problems in the development of characteristics of machines determined from test and predetermined from design data together with a large number of short fundamental carefully planned problems in connection with the daily recitation and possibly a few long problems requiring several weeks of the student's available time outside of class of the nature of engineering reports and theoretical developments involving a large number of steps arriving at a logical conclusion based upon different fundamental concrete values for different groups consisting of a few students each, it is the belief of the writer that the best possible results may be obtained. If such administration receives the personal attention of an experienced instructor the evils of the two extremes mentioned above which are so often found in the administration of university work may be avoided.

ALL-YEAR SESSION, INDIVIDUAL INSTRUCTION: RENEWED SUGGESTIONS.

BY W. G. RAYMOND,
Dean of the College of Engineering, University of Iowa.

Ten years ago the writer made his first plea for a radical change in engineering school practice, principally advocating two things: (1) all-year sessions with brief and somewhat regularly arranged vacation periods; (2) individual instruction so arranged as to permit a student or a small group of students to advance through the course as rapidly as their ability and industry would allow.

The suggestions met with derision at that time—almost universal derision. But one by one some of the strongest opponents of the proposed change have become its advocates at least in part; and from time to time as various criticisms of present methods have been presented to the Society, the writer has reminded the Society that the cure lay in the adoption of the suggestions of 1901.

The writer has never been able to try out the experiment of an all-year session, but he has been able to experiment with the individual method of instruction. The success of the experiment has been told before this Society.

To the knowledge of the writer three schools have adopted the all-year session plan—the Thayer School of Civil Engineering in Dartmouth College, the University of Chicago which had adopted it (although unknown to the writer) before his suggestions were made, and the University of Cincinnati in connection with its co-operative courses in engineering.

Criticism of the engineering schools has not been wanting during all these years, but this criticism has not been confined to engineering schools but has reached pretty much all schools of higher education as a class; and, while the writer recognized the splendid work that has been done by the better men who have graduated from various technical schools, he is still of the impression that these schools are not efficiently conducted and that we as a Society pay too much attention to small details of teaching and laboratory arrangement, etc., and not enough to the greater problems of general organization and administration.

The Thayer School of Civil Engineering is essentially a graduate school of engineering lap-jointed (to use one of Professor Jackson's expressions) with a course in arts. The co-operative system of Cincinnati is not suited to all or even the majority of universities, and it is probably safe to say that it is limited in the extent to which it can be developed in Cincinnati.

Admitting for the moment that some of the criticism of the engineering schools is well-founded (and the writer believes that some of it is well-founded), the difficulties cannot be met everywhere by the Thayer School method nor by the coöperative method of Cincinnati. But the writer believes that practically all the difficulties that really exist can be met by every institution by the adoption of the two suggestions made in 1901, namely, an all-year session and individual or small group instruction.

Whether or not one or more years of the course shall be devoted to practical work in a commercial establishment as is the custom in some foreign schools or whether the school shall complete its work with the young man before he enters commercial life at all, are matters of detail, as is the arrangement of the course to fit the seasons, climatic conditions, the needs of students who must be in part or in whole self-supporting, ideas of sequence of subjects, and other matters.

It is true that in some structures certain details must be designed before it is known that the proposed design for the structure as a whole is feasible. But the writer thinks that this is not true of his proposed school structure.

Engineering is now recognized as a learned profession and much more is demanded of the engineer both professionally and socially than in former years. To meet the increased demand he must have a broader training than would suffice fifteen or twenty years ago. This means that he must take more time for his educational work either by taking more years or by making his school years longer than they now are. The writer thinks that it is better to increase the length of the school year than to increase the number of years.

The charge is made, and it is true, that there is less of personal contact between the student and experienced instructor than there should be because of the large classes that are now taught. And, while this is true to a greater extent in colleges of arts and sciences than in engineering schools, it is nevertheless true to a greater extent than it should be in technical schools. This difficulty is met by the individual or small group method of instruction.

The all-year session and individual instruction methods being thus able to meet two of the principal criticisms leveled at engineering schools, it has seemed to the writer that the time has come to repeat the suggestions of 1901, and to ask the members of the Society to consider them carefully and to give voice to the opinions resulting from such consideration.

The writer is fully aware of the radical character of these suggestions, but he is fully convinced that the weaknesses in our present systems are not to be corrected by minor operations, but that a radical change of some kind must be made if any great degree of improvement is to be accomplished. And with all the criticism and all the discussion we have had during the past ten years he has heard no suggestion made that appealed to him as being so likely to improve faulty conditions, if adopted, as the suggestion of the all-year sessions and the individual method of instruction.

It is needless to answer that one or both of these will involve considerable additional expense. Such an answer should be met with the statement that we are not spending as much as we should, that the increased efficiency is worth all that it costs, and that when this is satisfactorily shown to those who supply the money the necessary funds will be forthcoming.

Discussion.

Dean M. E. Wadsworth: When I went to the Michigan College of Mines in 1887 the institution was one year old. It had been started with the idea that in order to make a successful technical school one must have teachers who know nothing of educational work, but who must have been in practical business for ten, fifteen or twenty years. No records had been kept of that year's work or of the students. The only information obtainable about the school was from one of the students who had attended the preceding year. Conditions in other *state* mining schools were not much better, although non-state institutions like Columbia, started when I began teaching in 1863, had always been successful. Colorado, which now stands as the largest school of mines in the United States, had then only thirty-one students, but had been in operation some fifteen years. The problem at Michigan was to make a success of a school which had nineteen students the preceding year, and of which its best friends said, "That school cannot be made to live beyond three years under any consideration." The ordinary routine course could not be used because students would go to well-established schools like Columbia, Lehigh and others. The course was two years long. From 1887 to 1889 I made the year thirty-nine weeks, which was about as long as I could do at that time. In the catalogue for 1889 and 1890 a three-year course, forty-five weeks each year, was announced, commencing in 1890. That three-year course covered 4,445 hours of rigid required work. The catalogue of 1890–1891 announced a rigid four-year course of forty-five weeks each year which went into effect in the year 1893. This course required for graduation a total of 6,950 hours. As far as I know, so hard a mining course had never before been established in the United States. The course was very severe on faculty and students in a region where the winters are so long. The course carried to the extreme the instruction in mining work. It took our men about ten hours a day in the class room, both summer and winter. This work was too hard for all and the remedy was found by my devising an elective system adapted to our conditions. Professor, now President, McNair at first declared this could not be done, but later the system was unanimously adopted by the Board and Faculty and is in successful use to-day.

In conclusion, I will state as a matter of history that the first use of the forty-five-week year, or continuous year, is attributed wrongly to the Chicago University. The Michigan College of Mines was the pioneer, as far as I know. Professor Harper was chosen President of Chicago University September 10, 1890. He accepted the presidency on February 16, 1891, and entered upon his duties July 1, 1891. The forty-five-week year was introduced by myself and in operation at the College of Mines before he was elected to the presidency of Chicago University.

Professor Elton D. Walker (by letter): I was very much interested in Dean Raymond's paper. For some time I have felt that it would be desirable to have our engineering schools in session all of the year, the work being divided into three or four terms, and so far as possible all subjects being taught in every term. In this way it would be possible for a student to enter upon his work at any time and to complete his course by working continuously throughout the year or by taking a vacation of a term or more at a time as he wishes. Of course, some subjects could not be taught satisfactorily during the winter months in our northern colleges, as the field work of surveying for instance, and similar reasons might prevent some other subjects being current in all terms. The teacher's work could be arranged, where more than one teacher was engaged upon the same subject, so that opportunity would be open for vacations even though the subjects taught were offered in all terms. The fact that some institutions now have their work arranged on this basis proves the practicability of the general scheme though the writer knows of no engineering school that has yet put it fully into operation.

Professor F. G. Higbee (by letter): A change from the present arrangement of the college year to a suggested all-year session could accomplish but one of two possible things: a greater amount of instruction in the same amount of time, or a similar amount of instruction in a less amount of time. From an administrative point of view such a change appears entirely feasible, practical, and efficient; from every other point of view the advantages of such a change may be brought into question.

If such a change is intended to remedy a defect so often charged against engineering schools—that engineers are not broadly trained men—it will fail. For while it may be granted that a broader training might thus be provided it could not be in such subjects as a knowledge of life, and of men, and of business and it is in such matters that engineering schools fail to give training. If institutions honestly desire to meet the criticism against the highly specialized and narrow training they now offer it is high time that they frankly admit that they can not give broader training in four years time and revise their curricula. The so-called vacation periods are to be considered as much a part of the whole scheme for a broad training as any other part of the college year for in them the opportunity may be had to see life, to study men, and to assimilate already acquired knowledge.

Again if such a change in the college year is intended to assist students to acquire an education in the shortest possible time it should be condemned by all men. If the commercial spirit of the times has any place in the social organization it assuredly is not in our educational institutions. Engineering training of itself is, unfortunately, commercial in its character and any influence which may be brought into engineering schools to leaven this unwholesome lump is to be welcomed. The faster engineering schools attempt to lead their students away from the "bread and butter" idea so common in education toward the idea of public service the sooner will engineering take and hold its proper place among the learned professions and the sooner will criticism of engineering education cease.

Individual instruction is a much misunderstood name for a method of teaching which, instead of being different from all other methods of teaching, is rather a combination of them. Whatever this method may be called it has merit not only because it has all of the advantages of the usual methods of teaching but also because it makes possible a supervision of *small* groups of students during the period devoted to *study*. It is upon this last point that emphasis should be placed. Lectures, recitations, and quizzes may be conducted as usual but each group of students should prepare for this work under the direction of an instructor.

For the last four years all work in drawing and in descriptive geometry at the State University of Iowa has been conducted in this way. Prior to that time instruction was given in the usual way with two laboratory periods for problem work. At present fifteen actual hours are required to be spent under the direction of an instructor. When the change was made it was expected that more students would be able to master the subject of descriptive geometry. While this did not prove to be true it was clearly demonstrated: First, That those who pass the subject have a wider knowledge of descriptive geometry. Second, That those who fail to pass have had a better chance to pass than under former methods of teaching.

It has always been made to appear that the great advantage to be gained by this method of teaching is that it makes it possible for a student to advance through a subject as rapidly as his industry and ability would allow. In the application of this method of teaching descriptive geometry at Iowa this feature has always been of minor importance. There is a stated amount of work which each student must perform satisfactorily in order to gain credit in the subject, and while students are always encouraged to work and advance as rapidly as thoroughness permits it is never with the ambition to get through the course in the least amount of time but always with the desire to get over the maximum amount of ground.

The great advantages to be gained by teaching by this method are: First, the thoroughness with which a subject may be taught. Second, the training which it becomes possible to give in the proper methods of study and work. Third, the intimate personal contact which becomes at once a pleasure and a profit to both students and instructor. There are some disadvantages also, chief among which is the difficulty of making a program when so many hours attendance are required; and also the difficulty of providing enough instructors when so much time is required for a single class. Certainly any institution which attempted to teach all its work by this method would find four years too short a time for a normal course in engineering, and also that a very considerable addition to its teaching staff would be necessary. It is the general opinion of those who have used this method of teaching here that it is most effective; and that it is not so easy for the instructor as the class-room method.

Professor Robert Fletcher (by letter): The session-year of the Thayer School of Civil Engineering does not extend through all of the calendar months, as suggested in the paper. During the first twenty years of its history the six-year period was in effect—engineering course of two years, following the degree of A.M. or B.S., earned by the four-year course in college. This has been modified during the last twenty years by the two-year engineering course following three years in college, earning B.S. in four years and C.E. in five years. Of the one hundred and thirty-five students completing the course in the past ten years exactly twenty per cent. have returned to take the fifth year, after staying out in practice from one to four years. The other eighty per cent., who nearly all had engineering practice during the summer intermission, might be credited with an all-year session—in so far that the first year begins within three weeks of the close of their junior year in college and continues forty weeks; and this is followed by the summer work period of eighteen or nineteen weeks, which is, however, entirely apart from the class-room instruction. Since the total membership of the last ten classes was nearly two hundred, it appears that more than two thirds took the five-year course. It is sometimes well to advise young men to stay out a year so as to gain the benefit of practical experience, and thus a better appreciation, both of the studies previously taken and those which are offered later. In rare cases where young men of conspicuous ability are somewhat mature and perhaps have had some little previous experience a continuous course is recommended.

Concerning the matter of individual instruction, there cannot be two opinions as regards the very great value of close personal contact between teacher and taught. Indeed personality is almost the governing factor in the most effective instruction. Such close contact is gained when the classes are small and the instructor is willing to devote himself to the duty of following up the student during the whole progress of the subject in hand. The writer's experience has been limited to classes not exceeding twenty-four, and he is free to admit that the larger number is not satisfactory even with recitation periods an hour and a half long. Ideally about fifteen is as many as one instructor can lead and feel confident that he understands fully each student's grasp of the subject. This close personal knowledge of each man's proficiency is only possible by rigid adherence to the policy of daily recitations from the best text-books; by the constant presence of the instructor in the drafting room to supervise and advise during each period of two to three hours; by field work so conducted that each party of four or five is under the immediate charge of a professor or instructor; by laboratory work either under the immediate guidance of the instructor or controlled by a prescribed program on which reports must be rendered; and by lectures only sparingly given to supply matter on which the text-books are deficient or not up to date. Other means found effective in directing and following up the work of the student are assignment of topics on which reports must be made, either from notes or from written papers read before the entire class at an assigned recitation period; also by suitable problem work in those subjects in which much is gained by the solution of well selected practical problems.

Dean Raymond is probably somewhat mistaken in supposing that his suggestions had first met with almost universal derision. On the part of the writer, and probably of many others, they received very respectful consideration. The very "logic of events" would convince any thoughtful person that school and college vacations have had a demoralizing tendency; having promoted unduly the vacation habit. People who have to struggle hard to earn their bread and butter, and who might be supposed to need vacations more than people of more leisurely pursuits, have to be content with vacations of two or three weeks in the course of a year, besides an occasional holiday. School teachers and scholars certainly do not, for any physical reasons, need two or three months. Much less do fairly well paid professors need the so-called "sabbatical year." While it is true that teachers of all grades need some leisure for enlarging their horizon and general education by travel and a wider contact with the world, yet even that need not take so much time; and there is now beginning to dawn upon the public consciousness a sense of the folly of having the large equipment of colleges, universities and even of the public school system lie idle during several weeks or months of the year. Undoubtedly in the near future very much more continuous use will have to be made of all these facilities and opportunities—whether provided at the public expense or by private munificence—than has been the custom hitherto. It is proper to say in this connection that the writer has generally not been able to get much more than a month during the entire year when he was entirely free from the responsibilities and demands of the institution in which he has taught forty years; although there have been exceptions in a few instances.

These remarks are offered at this time quite tentatively with the suggestion that the subject is worthy of very careful consideration and discussion by members of the Society; so that possibly Dean Raymond's startling proposals of ten years ago may finally result in a much more effective use of the valuable "plants" which represent such a very large amount of invested funds which should be more continuously productive of the best fruits in technical and general education.

THE TECHNICAL GRADUATE FROM THE POINT OF VIEW OF THE MANUFACTURER.

BY MR. E. B. RAYMOND,

Vice-president of the Pittsburgh Plate Glass Company.

I make these few remarks on this subject realizing fully my lack of experience in teaching. I do not pretend, therefore, to be competent to offer suggestions for improving existing methods. What I say, however, is based on an intimate business association over a long period with graduates of the colleges in this and other countries,—somewhat over two thousand men in all.

Four of the important characteristics in a young man are character, health, ambition and specific training in line with the work to be followed. I presume inheritance and home influence have the most to do with the first three, although undoubtedly the college has a tremendous influence, too, though not as much as with the last one.

To me, it seems absurd to expect a college in four years to turn out men freed from their natural weaknesses, when one considers the quality of the average human being who enters. It is impossible to produce, during four years, a technically-trained man with all the practical experiences that are essential for the proper assumption of authority in actual life. The average boy who enters a college requires tremendous development. It has been my experience that perhaps ten to fifteen per cent. of the graduates are of the highest class, embodying all that one could reasonably expect. About sixty per cent. of the men can be used for various positions and thirty to forty per cent. are unsuitable. Considering humanity as we see it, these figures are perhaps better than one might think. Presumably one of the vital questions under consideration constantly is how to improve the output.

Possibly it would pay to cite the undesirable characteristics which have been forced on my notice, that seriously interfere with the efficiency so generally desired.

One of these is laziness, a desire to get along comfortably, freed from as much mental or physical exertion as possible. It is hard for me to say what the college can do to alter this. If such men are dropped, the quality of the graduate will naturally improve. On the other hand, those dropped would lose the training and its help. From the point of view of efficiency of the graduate, such men should properly not receive a certificate.

Perhaps somewhat allied to the above, is the fact that many men are not willing to learn the practical end of the business they are entering. They are often unduly impressed with the immediate value of their education, and do not realize at all their unfitness for responsibility, and are not willing to make the sacrifice of time and comfort to complete their training. I have found this sometimes true of the best of men. Without this experience, which they lack, they go on for a while, but the handicap eventually holds them in inferior positions, and they never, probably, know why other men get the responsible positions, even without the complete technical training they themselves possess. The college would help if it could teach this feature and accentuate it by requiring during the summer vacations practical work in practical manufacturing institutions. I am quite certain that what I cite cannot be learned in a college workshop, although I am not prepared to state that these are not of value. It is possible that the possession of a few teachers who themselves have been successful practical men, with manufacturing responsibilities, would help.

Somewhat allied to the above, is the characteristic very positively noted with graduates, which is a remarkable lack of ability to assume responsibility, or even to carry out carefully instructions received. In other words, they cannot be trusted. There is a lack of seriousness in their point of view. They apparently do not know that a small duty well done has in it all the virtue of a big duty. I believe the college is partly responsible for this condition. During the course, the percentage of "good time" is perhaps too great. The view of the college life might properly look more like the view of the business office. It is my feeling that the college with a minimum amount of "college life," as generally interpreted, and a maximum of "office atmosphere," produces the best material. I do not believe in college life as popularly interpreted, and would cut it down to a minimum, replacing with "office spirit."

Another feature that is noticeable in graduates, is the lack of ability to become a part of the working man's life, and to get his point of view, and thus be able to properly guide him later on. This property is an important part of the practical training, spoken of previously. Often men will get one part without the other. Some men by nature, can never get it; others can if they appreciate the need. Possibly the average young man has never had this subject properly presented to him. Perhaps a short course in the senior year on subsequent and necessary training to complete the college course, would be worth while. Such a course to be given by an outsider of special breadth of experience.

Another matter that is not properly impressed upon all graduates is the fact that what they have learned is but a small part of what is necessary for their profession, and that regular study must be kept up. I have found that the average student ceases to study for several years after graduation. This tends to make him forget what he has learned and does not keep him up with his profession.

Another duty that the college does not always fulfill is the preventing of men from taking up a profession for which they are by nature entirely unsuited. I think the college could do better in this. The average young man does not know for what he is best suited. I have found this true of the average graduate, let alone the boy entering college. To me, it is not fair to the boy to leave it to him. It disturbs me to hear a parent say that the choice of life work is to be left with the boy. He is incapable of judging, with his lack of knowledge of life's requirements, of his own possibilities. Perhaps a college could have a committee to advise parents on this subject; or at all events, to go on record on the matter, weighing all the facts; the father's business, his circumstances, the boy's own view, and make-up. Perhaps a broad gauged practical outsider or two would be of advantage on such a committee.

Finally, and particularly, the graduates are not thoroughly trained in all the branches they have taken up. In general, there is not sufficient thoroughness in such essentials as mathematics, mechanics, and physics. The foreign colleges of Sweden, Germany and England, judging by the graduates with whom I have dealt, do better. It is possible that we try to teach too much, and therefore a great deal becomes imperfect. Perhaps the only solution is to drop some of the courses and be more thorough with those that are left. From the point of view of the young man who wants a general view of the studies of the world, or to know in a superficial way, what are the problems and records of the world, this would be a restriction. His interest would be stimulated in fewer directions, and he would be in a sense, narrower; but from the point of view of efficiency in the line he has chosen to fit himself to make the best fight, I would urge a great deal more thoroughness, more depth, and less width if necessary, to accomplish this. In saying this, I appreciate the many disadvantages, but for the purpose in view, I do not see how it can be avoided. The line of study which is omitted must be taken up by the man himself at a later time.

I hope it is not true that there is a desire in our colleges to be the largest, with the largest list of subjects taught, and the greatest publicity through athletics, etc. I hope nothing exists due to the spirit of the times which is causing a departure from quiet, earnest, business-like conduct along definite lines for a definite purpose. It is not proper to criticise without proper facts at hand; but, the thought has occurred to me, that it is possible that harm is being done in some cases from this cause. I do not wish to be interpreted as not being fully appreciative of the great value being done to this country by our colleges. Many a man owes his position, his happiness, and his faith in himself to his college influence. The college-trained man is essential for progressive organizations. Undoubtedly the large group of rare men who are studying this problem are guiding it in the correct general direction. It must be an inspiration to know what is generally admitted, that at present, there are more positions for the right type of properly trained college men, than there are men to fill them.

ADAPTING TECHNICAL GRADUATES TO THE INDUSTRIES.

BY C. F. SCOTT AND C. R. DOOLEY,

Pittsburgh, Pa.

The Westinghouse Electric and Manufacturing Company has recently modified its two-year course for technical graduates* principally by supplementing factory and testing-room experience with class-room instruction and by specializing the training in the latter part of the course, adapting it to the particular work which is to be followed later. The present paper outlines the conditions and the reasons which have led to the change and describes the general methods which are being followed.

A large step in engineering education was taken ten or fifteen years ago when it was recognized by the industries that the education of the engineering schools should be followed by specific practical training, and suitable shop courses were inaugurated for bringing young graduates into active contact with the apparatus and the methods of manufacture. For many years the Electric Company has received annually several hundred graduates. They have been regularly employed in factory, testing room, engineering department, and the various commercial departments.

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* In addition to the course for technical graduates, the following educational activities are carried on in connection with the Westinghouse Electric and Manufacturing Company, at East Pittsburgh, Pa.

1. A Trades Apprenticeship Course in which boys with ordinary public school training enter a four-year course, the purpose of which is to train them as skilled mechanics. They enter an instruction shop and are afterwards transferred to the regular departments where they are still under the supervision of the educational department. Each apprentice attends a drawing class two hours per week, and a class for general instruction, which deals with shop problems and elementary mechanics, for two hours a week. This instruction is given during regular working hours and the regular rates of compensation are paid. There are 214 apprentices in this course at present.

2. The Casino Technical Night School, having a regular four-year course. School sessions are held three evenings per week from September to June. The majority of the students come from the works of the Electric Company, although attendance is open to any one. A small tuition fee is charged. The teachers are principally engineers most of whom are connected with the Electric Company. There is also a department for young women. The enrollment last year was approximately 500, and there are about 40 in the faculty.

In this graduate student course the men were formerly transferred from department to department and were expected by contact with their work, to acquire a knowledge of the construction and use of electrical apparatus and of business methods. Supplementing the regular daily work, an evening lecture course was conducted during one season ten years ago. This was followed by the organization of a club with facilities for lectures, technical meetings and social activities. However, little was done in the way of systematic instruction bearing directly upon factory and office work. While much can be said in favor of a " sink or swim " policy and the value of learning things by personal observation and experience, the conclusion has been reached that better results, on the whole, will follow a modification of this former method, which is open to improvement for several reasons:

1. Electrical apparatus is now of so many kinds and has become so specialized that ordinary shop work is no longer a sufficient means of instruction. Furthermore, a fuller knowledge concerning the details of construction and the principles of operation is now essential to the designing engineer and the application engineer than was formerly necessary.

2. Factory work by a beginner is apt to be inefficient from the standpoint of the employer and the ordinary young man has difficulty in observing and in learning what he should do. The transition from the prescribed lessons and personal supervision of the school life is too abrupt.

3. The point of view is apt to be that of the workman who knows only of the construction of the coil he winds, or the arc lamp he assembles, without appreciating why the appara-

tus is made as it is, in order that it may be reliable, durable and efficient. He may learn what it is without learning why; he may miss entirely the ideas of the electrical and mechanical designers which are embodied.

4. The time available in the factory is too short to enable one to cover the whole ground thoroughly, hence factory experience is ordinarily limited to a few departments and a few kinds of apparatus. The course must cover but few departments if it is to be thorough, while if it endeavors to cover all departments uniformly and comprehensively, it becomes too superficial.

To meet these modern conditions, a new method of training has been inaugurated for the graduates who are now entering the course. The following presents a general outline of the plan and policy which have been carried out:

1. The course is divided into two periods. The first is given to general training in the factory and testing department, while the second, is special, fitting men for the engineering, sales or other departments.

2. In the first period, the work in the factory and testing room is, in the main, confined to a few departments, where the essentials of winding, assembling and testing occupy most of the time and in which a reasonable degree of proficiency is required. Each man enters one of the general departments of the factory; such as the railway and control departments, where railway motors, locomotives and controllers are made; or the industrial department, where small motors and controllers are produced; or the power department, where large generators and motors are manufactured. Each of these departments is essentially an independent factory, carrying on complete manufacturing and testing operations.

3. Supplementing the factory organization, there are supervisors who assist the foremen in making the work of the graduates effective in the regular manufacture of the company's product, and at the same time aid the young men in acquiring useful knowledge and experience. The shop work is of a practical, serious sort in which the young men learn

to be workers and producers and develop a sense of service and of vital responsibility.

4. Supplementing the work in the factory and testing department, a course of technical instruction has been started which comprises attendance at class-room meetings during working hours, for approximately four hours per week, during which time the regular rates of compensation are paid. Also the equivalent of at least six hours per week outside of the regular working hours, is required to be devoted to assigned reading, study or technical meetings. This technical instruction relates particularly to the construction and operation of the apparatus and it directly supplements the work in the factory. It is proposed that the men who are working on a particular kind of apparatus will have an instruction period devoted to it each week. Instruction books or appropriate articles may be assigned for reading, a list of questions may be given to the students beforehand, and in the class-room there may be questions, general discussion or talks by the company's experts. For example, on a certain day those who are winding coils, will meet in the class-room and under the guidance of an instructor, will consider the types and forms of coils, the various methods of forming odd-shaped coils, the characteristics of the insulating materials and methods of applying them, the insulation required on coils of different sizes and for different purposes, the methods of splicing wires and copper strap, the machine-winding and hand-winding of coils, also the cost of the materials and labor. The more purely engineering features, as the ventilation, carrying capacity, eddy currents and the like, will receive only secondary consideration at this time.

5. General instruction regarding the various types of apparatus supplements that relating specifically to the factory or testing room work upon which the men are immediately engaged. Thus, comprehensive acquaintance with all types of apparatus is gained through reading, discussions and lectures, accompanied by visits of inspection to the various departments of the works. The young men will be called

upon to observe for themselves, and to make written and oral reports. For this purpose evening meetings are held.

6. At the beginning of the second period of the course, the young men take up the special training for the engineering, sales or other departments. The experience in the first period places both the young men and the company in a position to make an intelligent selection of the departments for which they are best fitted.

7. The several departments have direct supervision of their respective training courses. In some cases the work continues in the factory and the testing department along particular assigned lines. In other cases, regular work, under proper supervision, is done in the engineering, sales or other departments, while, in still other cases, a portion or all of the time may be devoted to special study and class room exercises.

8. The sales department has been conducting, during the past year and a half, a commercial training department for the engineering graduates who are completing their courses and are to become salesmen. These young men study the company's publications; they answer specially prepared questions on the construction and application of the various kinds of apparatus; they give special attention to the engineering and commercial features in the application and use of electric motors as applied to different industries; they become familiar with the details of the system by which the company conducts its business; and they make a study of scientific salesmanship. Part of this work is under special instructors, and part is under the supervision of leaders selected from the class. In the study of apparatus, frequent trips are made to the factory and smaller apparatus is brought to the class-room. Sales demonstrations in which students endeavor to sell arc lamps, meters, or motors to other students or to engineers or salesmen, are fruitful methods of testing a man's technical knowledge, his resourcefulness and the force of his personality. At the close there is review and criticism by the class and the experts.

9. The engineering department is actively maturing plans

for training men for its work which will combine experience in factory and in the engineering department in a way most effectively to train men as designing engineers.

10. In addition to the above, during the second period, particular courses will also fit men for the manufacturing, the testing and the erecting departments.

11. The instructors who have immediate charge of the various departments of the training course are specially fitted by education, experience and temperament. Most of them are technical graduates, who have taken the apprenticeship course and have had several years of practical work. They have at hand for guidance and counsel the various officers and engineers of the company and, when needed, they can call upon them and the experts and specialists in various departments for assistance in the educational work which they are directing. This will bring the new men into contact with the older men of the company.

12. The Westinghouse Club, formerly The Electric Club, which has just closed its first year in new quarters continues to contribute to the welfare of the graduate students. During the past year there has been a weekly course of high grade lectures on general topics. There have been seventeen technical sections, each meeting every two weeks, and each dealing with some type of apparatus or its application or some phase of the company's organization. The older engineers have taken an active part in these meetings. Excursions by the young men in a number of groups have been made to a score of industries in and about Pittsburgh.

The club provides a convenient social headquarters for the young men. There are a dozen rooms for reading, writing, general gatherings and amusements, as well as lectures and formal meetings. There is also a large and well equipped gymnasium which contributes to the physical welfare and athletic enthusiasm of the members. The dues, for those on the graduate course, including the gymnasium and *The Electric Journal*, published monthly by the club, are $7 per year.

The club activities are managed by young men who find this an excellent means of getting into close contact with their fellows and of showing their aptitude for organization and management.

13. Underlying the purely technical knowledge and experience which nominally form the principal content of the training course, there is the even more important purpose of developing men. As the electrical industry increases and more exacting requirements are placed upon electrical apparatus, which is taking a larger and more responsible part in the doing of the world's work, there is demand for greater ability on the part of the engineers and managers who have to do with the production and operation of apparatus and the direction and management of manufacturing and operating companies. Many of those who now hold responsible positions in the various departments of such companies or as consulting engineers, have gained an important part of their experience in the training courses of manufacturing companies. It is the aim in the plans which have been outlined in this paper to keep pace with the new conditions and to prepare men for the larger duties and larger responsibilities which they will face in the future as engineers and as men.

THE COOPERATIVE SYSTEM OF ENGINEERING EDUCATION AT THE UNIVERSITY OF PITTSBURGH.

BY F. L. BISHOP,

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An educational institution resembles, in some respects, a manufacturing concern. The manufacturing concern is, however, usually operated to produce a maximum output at a minimum cost, while the educational institution should aim for a small number of exceptional graduates almost irrespective of cost. The goods produced must be of such design, finish, material, etc., as to satisfy its patrons; likewise, the graduates of educational institutions must meet the requirements of the concerns which are to employ them. The undesirability of the output of a factory may be caused by poor material, poor workmanship or poor design. The cost may be greatly enhanced by antiquated methods of production. The inefficiency of a graduate (and I apply the word "inefficiency" to include all the undesirable characteristics) may be caused by poor material, due largely to improper preparation of the student at entrance to the college or to poor instruction, poor teachers or antiquated and improperly-correlated courses.

The establishment of apprenticeship courses for engineering graduates in such concerns as the Westinghouse Electric and Manufacturing Company, and in fact in nearly all fair-sized manufacturing concerns, is an acknowledgment by these concerns that the output of our engineering schools is unsatisfactory. If now a certain amount of the work required by these concerns after graduation can be done before, it is at once evident that the graduate will more nearly meet the requirements of his employers. It is the purpose of this paper to describe the system adopted by the School of Engineering of the University of Pittsburgh by means of which its graduates in the future will be better prepared to enter upon their work as engineers.

The adoption of a co-operative system, I believe, is a logical development of engineering education in the United States. When engineering schools were first established they were really schools of pure science. These proving unsatisfactory, as judged by the output, shops were taken into the schools and shop-work made a part of the curriculum. Now shop-work is, and probably always will be, an important agent for training the hand and eye. But when a school shop attempts to represent actual commercial conditions it is a total failure. The next step was to take the student to the shop, and at the same time to retain and add to those portions of the shop-work in school which have produced satisfactory results.

Because of the remarkable industrial environment of this school, it is especially well situated to apply the coöperative principle to the education of young men who are preparing to enter the engineering industries. The plan adopted is as follows:

The school year is divided into four terms of twelve weeks each, including the summer term. The freshman enters at the beginning of the fall term and remains in school during the whole of his freshman year. During the sophomore and junior years he spends one half of his time in the shop and one half in school, interchanging every three months. His entire senior year is spent in school.

We hope to accomplish three things by keeping the freshmen and seniors in school:

1. By means of lectures given by practicing engineers, visits of inspection, consultation, etc., the freshman obtain a fairly clear idea of the work expected of an engineer, and is better able to decide, not only whether or not he wishes to become an engineer, but also what kind of engineering work he wishes to pursue.

2. The faculty becomes acquainted with the students and consequently can eliminate the undesirable ones and at the

same time turn over to the manufacturer only those whom they think will make a success in engineering work.

3. The work of the senior year can be based not only upon the usual amount of theoretical and laboratory work, but also upon a year of practical work. It is evident that this arrangement will help the senior by making his work more interesting, giving him a better grasp of the subject, and increasing his interest in such subjects as economics, etc.

The school work under this plan consists of 128 weeks, which is 8 weeks longer than the course at the Massachusetts Institute of Technology. In addition to this, the student has twelve months of practical work in the space of four years. The school work is so arranged that successive groups of students furnish continuous service to the employer.

The work is conducted under actual commercial conditions. Thoroughly practical knowledge can be had only by actual work in the engineering industries and should be required as early as possible. Working side by side with other employees, students get an insight into labor conditions. Detailed observations of engineering work and the conduct of business, from the productive point of view, gained in the students' formative years, is an invaluable addition to knowledge gained from text-books and instructors. Although the university has made special arrangements with local industrial concerns and will co-operate with these concerns, in all possible ways, for the benefit of its engineering students, students are regarded as direct employees of the concerns. They serve for six working days each week, receive the pay of workingmen doing the same class of work, are required to observe the regulations of the company, and are subject to existing labor conditions and laws, including those pertaining to liability for accidents. This industrial practice is arranged, so far as feasible, to provide every student with an opportunity of working in the branch of engineering in which he is especially interested.

Each student reports to the proper instructor one evening of each alternate week, for discussion of his practical work; at the end of the term, on presentation of a written report of his work and observations, he receives twenty credits.

Mr. S. M. Kintner, general manager for the National Electric Signaling Company, gives the manufacturer's point of view of the plan in the following paragraphs:

"To him it is a strictly business proposition. He does not undertake it from any motive of philanthropy. He expects a fair return in labor for the money that he expends. He does not expect to have the general discipline of his force interfered with and cannot, therefore, grant any special privileges. He offers the student an opportunity to see and study his works and methods while carrying on certain duties to which he has been assigned. He realizes that there will be a certain advertising feature, as the students will know of his product, will talk about it and possibly be instrumental in making sales of it as they go out into actual engineering work upon the completion of their course.

"The manufacturer sees still another advantage for himself in the plan—it puts him in touch with a number of young men who are just starting their training for lines of work in which he is interested as an employer. He is afforded an opportunity of looking over these men and picking out such of them as appear particularly good. He can then suggest certain lines of training that will fit them for his requirements, and he, in this way, has a chance of training up picked men for his force without expense to his company."

From the student's point of view, we hope to accomplish several things:

1. We believe that under the old system many students became engineers who would have made better preachers or lawyers. It seems fair to assume that if a man has had one or two practice periods in the shop or in field work, he will know for a certainty whether or not he is fitted to take up engineering work. If he does not know, his employer undoubtedly will.

2. He will come into contact with the ordinary laboring man, and will be afforded an excellent object lesson of the relative value of muscle and brains. It will undoubtedly lead him to a wholesome respect for labor and tend to give him a higher estimate of the value of brain training. He will be in a much better position to handle workmen later in life from his knowledge of the workman's ideas of his duties to his employer, etc.

3. In his university course everything is done for him; in his practice work he will find that he is doing things for everybody. He will find that seven o'clock means seven o'clock; and the discipline he gains by constant, regular and perisitent work will be of great value to him.

4. He will have an opportunity to study manufacturing concerns and organizations in their dealing with employees, in their methods of transmitting orders or technical information, in their methods of keeping records of their tools, materials, and finished product, in their method of keeping the time of the men and paying them.

5. He will make acquaintances and form friendships that will later be of great value to him in securing positions, in obtaining advice, etc. He will have a chance to ''make good.'' Many men in school decide that they will go through school in the easiest possible way with the determination that as soon as they finish their course they will turn over a new leaf and make a fine record. The co-operative work will undoubtedly cause them to make good resolutions much earlier in life because the university will not retain students in the school of engineering who fail in their co-operative work.

6. Familiarity with actual engineering conditions will give the student confidence and a broader view of things. He will be able to secure more information from his instructors, and will be able to enter into class discussions.

I might mention a great many other ways in which the students will be benefitted by this co-operative work as for instance, the pay he receives, his ability to do things, his independence as a wage earner, regular habits of study and work, increased efficiency, opportunities of employment upon completion of his course, etc., but it seems better to me to wait until we have facts upon which we can base certain conclusions, at which time I shall be glad to present to the Society further information concerning the co-operative work.

Discussion.

Chairman Kent: Before opening the discussion I want to say a few words. Let us see what position the engineering teachers are in from the business man's standpoint. This is our product, one hundred per cent., divided into ten per cent. of first-class men, sixty per cent. or ordinary men and thirty per cent. of failures. When I lived in Pittsburgh thirty years ago the condition of producing castings was this. We could buy first-class No. 1 foundry pig iron for $25 a ton. We paid $45 a ton for cold-blast charcoal iron, a difference of $20 a ton, because of some supposed superior quality that the latter iron had. There was another iron in the market called "mottled and white," a very hard iron, that was very low-priced because it was good for very few purposes; and there was another iron that was extra soft, an accidental product of the blast furnace for which it was difficult to find a market. Somebody discovered that one of those irons that was low in price, extra soft, was exceedingly high in silicon. They also discovered that the other iron, the white iron was low in silicon. Some bright genius said that one per cent. plus three per cent. makes four per cent. and divided by two makes two per cent. So that adding soft pig iron, high in silicon, to hard pig iron, low in silicon, gave medium silicon just what was wanted. For hundreds of years the extra soft and the extra hard irons had been undesirable products. We must grade our students along somewhat analogous lines and we must have some psychological process of finding how it is that our students are divided into those grades, and what use can best be made of each grade. Alexander Pope in his "Essay on Man," a hundred years ago, said, "Whatever is, is right." I believe that maxim has been a truth of Nature through all time. Now we are coming to believe that in engineering education whatever is, may probably be wrong, and we have to find out how to improve it. If there is anything that is probably wrong it is this fact that sixty per cent. of our students are second-class and thirty per cent. of them are failures. I do not believe that this is due to human nature. I believe there are methods of analysis for finding out the cause of this difference, and some day we will change the present condition and then be able to say that we have twenty per cent., instead of ten per cent., of first-class men, and will have not over twenty per cent. instead of thirty per cent. of failures, and we will have different gradations of the sixty per cent. remaining. We must try experiments of all kinds, such as Dean Wadsworth and Mr. Raymond are trying, and as is being tried in the Westinghouse works to find out how to treat students after they come out of college.

Dean J. P. Jackson: I shall have to plead guilty to the word psychology, as referred to by Mr. Dooley, because the subject under discussion is really a matter of psychology and character building to a very large extent. I believe one cause for the existence of that unsatisfactory sixty per cent. is that we teachers are apt to go into the school room and teach about steam engines and other material things—expounding upon the forces of nature and their workings, but often times neglectful of the human element. After all, the manufacturer will not knowingly employ a man, who, although foremost in a knowledge of pure cold science, has not the proper character. Our old colleges of which religious denominations or other organizations usually had charge, made certain requirements that are now sometimes lacking. They had Bible study and, however neglected in the practice of the present, there is something very useful in such a study. Then there were in force other methods of handling young men, that tended directly to develop character. We now seem to hesitate to put into our engineering catalogues much about the specific training of character and manhood, or work for the spirits or the souls of the youths in our keeping. Is this right? Should we not formally construct and announce methods that will train the boy in loyalty, industry, originality, kindliness, a regard for spiritual life, citizenship, the relation of man to man in the various pursuits and businesses of life, and any other subjects that tend to the development of full manhood from the time the youth enters as a Freshman until he steps forth as a graduate? Should not this work be as frank and direct in the teaching of mechanics, rather than incidental as is so often the case?

Dean Snyder has proposed a scheme for a co-operative course, which I assume fits his conditions and likely will fit the conditions at some of the other institutions of learning. Dean Bishop has proposed a scheme which is more flexible and which could be adopted by most of the engineering schools of the country, however located. Regarding the proposed system and the discussion on shop-work, I wish to express my belief that, unless we can persuade our high schools and our academies to give shop-work,—teach the boy something about using his hands with his brain,—we cannot afford to dismiss shop-work entirely from our college curricula. The student may go into commercial shops and learn shop-methods, but he is not going to get the same kind of value from an educational standpoint as is to be obtained in the school shop. Therefore, if you are going to give up your college shops, I suggest that you use your influence for the wider establishment of manual training in the high schools and academies. I have seen, in the cases of hundreds of boys, how valuable shop-work has been to them. Do not let us throw away a valuable asset merely because, in the opinion of a few men, it is valueless.

At Pennsylvania State College we started over a year ago to require in addition to the one hundred and sixty regular college credits, a certain number of extra credits for summer work. The boy has to perform this extra service in order to graduate. If for any reason, due to a slump in business or otherwise, he is unable to get a summer position, we provide a method whereby he can do an equal amount of work in the college. We put the plan into operation last year and about ninety per cent. of our boys now spend the required two months during the summertime in industrial work. They bring back with them in the fall statements signed by the superintendents, managers, or other responsible officials—in whose employ they worked—describing the work pursued and stating that the young man has done his duty to the satisfaction of those concerned. This arrangement results in every student getting practically six months of training in industrial establishments during the four years. We are inclined to believe that these six months, with an industrial post-graduate two-years' course of mental and hand training, such as Messrs. Scott and Dooley describe, will turn out as good men as can be produced by other systems which have been proposed.

Professor G. H. Morse: The last speaker advanced one of three reasons for the trouble behind Mr. Raymond's percentages. I would not minimize what he says with reference to either eliminating those who have not character or instilling more character into those that we have to deal with. What I believe is, that there should ultimately be some form of selection of students who are to take engineering. I think that at least half of those who present themselves to take engineering ought not to be permitted to do so. We should eliminate them through a psychological investigation of individuals. I believe that psychological tests could be produced that would very quickly eliminate a large percentage of those who should be eliminated. I understand that the old Romans had such tests. And to indicate roughly what such tests should consist of I will give a simple example. In testing the ability of any man I would advertise that I would interview young men at a given address in a given city with reference to their getting positions. I would give an address somewhere in the neighborhood, but not the exact address. The fellows with energy, ability and anxiety enough to hustle around would find the right place first. This would be the first element in the elimination. That method sounds crude. There is, I understand, among psychologists today a much more scientific method* than that, a measurement of what I believe James calls our perservation. Flashing lights pass before the subject's eyes, and the number of flashes per second that must be reached before the person considers the light continuous is the measure of his capacity for a perception, or his power of retention of images in the brain. That, I understand to be a very accurate measure of certain capabilities that would tend to differentiate between geniuses, lunatics and people of average intelligence. And I believe a test based on some such scientific method as that would go a long way towards eliminating the undesirables in engineering schools.

After having chosen a proper and select number of students, the other element that I have in mind is the improving of the efficiency of methods of teaching. I have studied the methods used in the public schools since my day as a student in them. I have observed the development of school teaching of that grade through my children. I believe that the efficiency of methods of teaching used in the secondary grade has risen from say twenty per cent., in my day, to eighty per cent. today. Possibly the teachers in these lower grades now understand ways of teaching by more advanced methods to such an extent that they can instill eighty per cent. of what they attempt to teach. We college teachers instill about ten to fifteen per cent. of what we attempt to teach. I mean by this that if we take all the subject matter that we place before our students as the denominator, and for the numerator all that they are able to give back to us a little later, the ratio would be about ten to fifteen per cent. This casts no reflection on you or on me. There is no reason to feel that we are missing our functions. It is simply due to the extreme rapidity of the development which the subjects that we deal with have undergone. The *science* of teaching such subjects as engineering has not advanced to perfection because there have as yet not been years enough for it to do so.

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* See "Measuring Your Intelligence: John Gray's New Instrument for Testing Perseveration." *Scientific American*, Jan. 28, 1911.

Professor J. C. Tracy: A sentence in Mr. Raymond's paper suggests a phase of work which I consider very important. It is, in substance, that it might be well to have less college life and more office spirit. I think that I understand what he means by that kind of college life and I agree with him that it would be well to have less of it. I think that I understand what he means by office spirit, and I heartily agree with him on this point also. It seems to me, however, that there is danger of neglecting college life in its highest sense. Last year it was my privilege to spend two weeks at each of the large state universities in the middle west: Illinois, Wisconsin, Minnesota, Purdue and Michigan; and then two weeks at each of the five large universities of the east: Harvard, Massachusetts Institute of Technology, Columbia, Cornell and Pennsylvania. As I had made up my mind at the start that my principal object should be a study of the methods of instruction in civil engineering subjects, I spent most of my time in the civil engineering departments, and my impressions may, therefore, be considered rather one sided. And yet a man cannot spend two weeks at a university without getting impressions of university life as a whole. After my trip was over, and I had time to reflect, there were two distinct impressions that came to me. One was that I had never seen a body of men more intensely in earnest than the engineering professors and instructors whom I met on that trip. My impressions are not the same in this respect as those of Mr. Taylor. I feel that if the efficiency of engineering instruction is low, it is not because the instructors are not trying; and moreover, although the *absolute* efficiency may be low, it is high as compared with the efficiency of instruction in other departments of the university. I want to contribute this bit of testimony from the point-of-view of a man who has been able to observe the work of so many instructors.

The other impression which I gained was that there is some danger that these very men may forget that engineering is not the entire object in life. I saw many men who apparently thought of nothing, talked of nothing, dreamed of nothing, but engineering. Not all were that way, of course, but it seemed to me that there was a tendency in that direction. If this were allowed to go on for a number of years it might result in a large proportion of our engineering instructors and professors becoming engineering mad. Mr. Raymond's statement, taken at its face value and the percentage being granted as correct, is only a partial statement after all. He has measured men by their ability in engineering work; he has not, of course, attempted to measure men as men.

It is perfectly true, it seems to me, that of that sixty per cent. of men who take engineering courses who are failures as engineers, there is a very large percentage who, nevertheless, will do their part well in life, largely because of their college education. And I am not sure that it would be wise to bar from our engineering course men who are not adapted to engineering work, because our engineering courses are, perhaps, as well fitted to turn out *men* as are other courses. Nothing in this meeting has pleased me more than to have Dean Jackson touch upon the fact that the end of education is not altogether engineering; that engineering is not an end but only a means; that after all it is our business as instructors in engineering not only to train men for engineering, but also to train men for life. And I wish to enter an earnest plea at the end of this session that we do not forget that.

In my remarks I do not wish you to feel that I am comparing any sections of the country. The worst offender that I observed was an institution which required so much time of its men that there was nothing for those men to do but to work incessantly, either in the class room or out of it. This institution is located in the east. The next worst offender, in my judgment, is located in the middle west. The fault does not seem to be particularly characteristic of any section of the country, but it is a danger which our very earnestness and intensity of purpose as instructors makes all the more real.

Professor H. S. Jacoby: I wish to express my appreciation of the excellent remarks by Mr. Raymond, because we have heard so much destructive criticism from those employing the young men who are turned out by our engineering colleges. This paper certainly gives us constructive criticism, and I hope that we may get more of a similar type. To learn the point-of-view of men who are employing our embryo engineers, and the results of their observations in the training of character, certainly ought to be very helpful to all who are endeavoring to do their best to train those men.

There are two points in the paper to which I wish to call attention. A reference was made to the duty of the college in regard to dropping students for poor scholarship. The inference is made that a man who is dropped by a college will entirely lose the opportunity for an education. Now if a young man has failed to react to the forces which were brought to bear upon him in one institution, it seems likely that to be dropped out of that institution should be of real service to him. He can go to some other institution and continue his work, perhaps under very different conditions. He has probably changed his attitude toward study, which he might not have done so easily if the change had not been made. That is, we ought to be willing to recognize that there are other engineering schools in the country to which he may go, where good work is also done; and that he is not entirely prevented from obtaining an education. We should not, therefore, allow our sympathy to prevail rather than our judgment.

The other point is based on the reference made by Dean Jackson in regard to shop work in industrial establishments during the summer. Frequently the colleges have been criticized for not encouraging this practice more generally, and in some cases for not giving more work of that type in the college. It seems to be well worth while on every possible occasion to remind fathers of the duty to secure for their sons some practice in manual work long before the boys enter the engineering college. If in the latter part of their grammar school course and especially in their high school period, the boys could engage during vacations in manual work and get in contact with business life and people, it would be a decided help to them in college. I have tried as a father to carry out this idea, and believe that it has been very profitable. Every boy ought to know how to use his hands, and ought to feel that he can construct something, and that he is not comparatively helpless when he goes out into practical life. I am pleased to learn of the plans for such courses here in the University of Pittsburgh and shall look forward with interest to the outcome.

Dean Wadsworth: I wish to refer to practical work, in mines, of co-operative practice. At the Michigan College of Mines we did on the outside the same shop work and field work in surveying and work of that kind as was done long before at Columbia and various other engineering schools. This not proving satisfactory we made a change putting in what is now called co-operative work, which we always called practical work in connection with the mines. This gave the student a chance for real work during the vacation or during the term. The plan proved an absolute failure, for the simple reason that the mining people were not up to us. There was not a single mining engineer in a copper mine in Michigan at that time except one at the Calumet-Hecla, who was a civil engineer, a graduate of West Point. Today every man is an engineer. In the Pennsylvania State College, of which Dean Jackson has spoken, I had charge of the school of mines in 1897, and we had an arrangement whereby the men could begin their vacation in June, and spend twelve weeks with some company, satisfactory to the faculty. They were required to write a thesis upon the work done and to pass a written examination upon it. The same plan has been introduced at the University of Pittsburgh.

Professor Hunter: I think the first cause that Mr. Raymond gave as a reason of failure in engineers was laziness, and he gave a fine definition. It strikes me that a great many of our institutions are unconsciously training students to be lazy. We are teaching students to think in terms of semester hours in place of the eight-hour day that they will have as the time unit after they get into practical life. The student comes to the engineering building or class-room and works for an hour and then probably has to lay off an hour for the next class. That time he will probably spend loafing or smoking or playing tennis or some other game, and then he will work another hour and take another rest. In place of having our laboratories and drawing rooms open at all times, so that the men can come and go and work, begin at eight in the morning and work until four or five o'clock in the afternoon, they are not allowed that liberty and they work at odd hours in place of all day. I like to see a man going to the engineering building at eight o'clock in the morning, staying there until it gets dark in the evening, and putting in his time to advantage during the entire day.

Professor Chas F. Scott (by letter): "The establishment of apprenticeship courses for engineering graduates * * * is an acknowledgment that the output of our engineering schools is unsatisfactory." Is this really true? I think not, if it is implied that "satisfactory" graduates would make such courses unnecessary. Rather, is it not true that during the past decade the technical graduate has come into general favor because he is no longer expected to be a trained practical expert when he gets a diploma, but is presumed to have a preliminary training which will enable him to acquire readily the special training and the practical experience needed in his chosen profession? There is a great deal in the industries which they themselves must furnish, which it is not only impracticable for the technical schools to supply, but which it is not their function to furnish. It is the function of the schools to make good beginners, and the specialized training upon which the vitality and development of an industry depends must be fostered within the industry itself. Hence, the postgraduate course in the world's workshop is normal and proper—a logical supplement to the technical school and not a reflection upon its efficiency.

I take it that the greatest value of the co-operative system which Dean Bishop describes is not that it supplies a big practical laboratory in which the student's technical knowledge is increased, but that it helps to make graduates better beginners. A present difficulty with many graduates is that they have so long breathed only the atmosphere of the school where the purpose of everybody is to teach them something that they catch pneumonia in the chilly surroundings of real life where they are expected to do something for somebody else. Then there is also the seriousness of doing one thing nine or ten hours a day, week after week, instead of taking half a dozen subjects at a time in hourly doses along with as many more varied outside interests. The transition will be much easier, the graduate will be a much better beginner, if he has breathed factory air and responded to the seven o'clock whistle in earlier years.

Many students learn what is in the book but do not comprehend the real physical thing. The formula is the thing they feel familiar with, the phenomenon is an indefinite something which is explained by the formula. One of the hardest tasks of the teacher is to counteract this tendency and lead the pupil to think and feel nature's laws for himself. Formulæ then become merely a convenient short-hand method of expressing them, worthy of no more reverence than the stenographer's notes of a great speech. Just as judicious laboratory exercises give definite meaning to what may otherwise be hopelessly vague and abstract, so judicious work-shop or other practical experience may give definite meaning to the whole college life, making clear to the student the rational purpose of its training in fundamental things, affording him an intelligent insight into the relations between the college world and the larger world, and inspiring in him a new and concrete interest in his studies because he has learned to appreciate that the college course itself is a sort of formula which stands for the things in serious, practical life. This new attitude of the student to the later years of the college work is one of the best features of the co-operative method.

The paper points out the serious and to some students disappointing fact that the manufacturer is not running a shop school but a commercial business in which young men are likely to acquire more in the way of general discipline than of technical information. And it is well that this is so, for more graduates fail for lack of the ability to get along efficiently with other people than for lack of technical knowledge. Hence the value of the experience and the new point of view which early contact with working men and with real things are apt to give.

I believe that when the employers of graduates say they are "unsatisfactory" it is usually not because they are not full-fledged engineers, but because they are not good beginners, and the co-operative system may be made an effective means of supplying some of their important deficiencies.

Mr. C. R. Dooley (by letter): Another university has established the co-operative plan with a schedule alternating at a new frequency. However the details of its schedule and plan of operation are relatively unimportant. We are more interested in the fact that the University of Pittsburgh has put its stamp of approval upon the general scheme and has seen the exceptional possibilities afforded by the industries of the Pittsburgh district.

Many of us may not agree with the details of Dean Bishop's schedule, methods of shop supervision, etc., but these points are not open to debate—local conditions determine them completely.

The success of any plan does not depend so much upon the details of its application as upon the character of its administrators. And there is a feeling among the industries of the Pittsburgh district that the university will succeed in its new work.

The principle of the co-operative plan seems to be a part of the natural order of things. The routine work of the day and the reflective research of the leisure moments follow in endless cycles throughout life, if one will reach the highest success. Study and service each has its greatest incentive in the other.

A number of years I have been interested in night school technical work, among regular factory employees—a form of co-operative education which taxes the ultimate strength of every student—and the general results which these men have accomplished would make the average college student ashamed of himself. The broad principle of co-operative education surely is the nearest approach to the ideal that has yet been conceived, at least for engineering and industrial training.

Mr. Alexander Taylor (by letter): Notwithstanding the criticism occasionally heard of the inefficiency of our technical colleges, it must be admitted that the work done by them has been productive of good results in supplying the engineering industries with young men who, with the practical training accorded them upon joining many of the leading manufacturing establishments, become well equipped in due course to carry on the various phases of engineering requirements. At the same time it is an equally safe assertion to state that there is still room for very considerable improvement, principally for the reason that heretofore the curriculum in each college has, in the main, been formulated without a sufficiently intimate knowledge of the needs of the differing industries.

Without attempting to set forth the several causes for this condition of affairs, some of which are, however, plainly to be seen, it may be said that college authorities and manufacturers alike, are now commencing to recognize more strongly than heretofore the possibilities in the line of service which each is in position to render the other and are accordingly beginning to get together in various ways, one of which is evidenced by the formation of co-operative systems of education as outlined by Dean Bishop.

As stated in this paper, it is hardly possible to enumerate all of the advantages likely to be derived from these co-operative systems at the present time. This is due to the fact that they are too new as yet, so that while sufficient is already known to warrant their further development, additional items of value will undoubtedly appear as time goes on, including particularly the percentage of time which should be devoted to practical training so-called, as compared with purely theoretical studies.

If criticism can be fairly made of the present college courses, it would seem to be that too much ground is covered in too short a period (4 years) for the average student to assimilate the subjects thoroughly, though this may be due, and doubtless is in part, to faulty preliminary training. Since the college course can, however, not be lengthened for the average youth, because of economic reasons, the studies to be taken up should not only be selected with the very greatest care but should be reduced in numbers as well, and additional time devoted to the remaining subjects.

The need for standardization both in the matter of entrance requirements for technical colleges as well as in the courses themselves, is fully as important as the need for standardization in manufacturing methods and appliances. The greatest step in advance will have been made, when this fact is fully realized and acted upon by the colleges; for the adoption of uniform standards by them will react on the preparatory schools compelling these latter in turn to make their standards more nearly uniform and in some cases, of higher grade, thus equipping students for more effective work.

The stage of co-operation now being entered upon by some college authorities and manufacturers, will if extended, enable a curriculum to be selected, the items entering into which will be studied more nearly in proportion to their probable subsequent value. It is true in all vocations that "practice makes perfect"; and it should therefore be borne in mind when formulating any curriculum, that studies once taken up should, if possible, be continued throughout the college course even if but indirectly, and not dropped upon the successful completion of an examination at the end of any term.

Besides permitting courses of instruction both in the colleges and in the shops to be laid out to better advantage, these co-operative systems of education will enable the students to see and to have impressed upon them, how very essential their college work will prove in actual commercial life, thus giving them an additional incentive, to make the most of the opportunities offered while in college. This point cannot be too strongly emphasized, as it is an advantage not accorded to the average college man under prevailing systems of education, except perhaps as he may, more or less unknowingly, make the opportunity for himself by working during his summer vacations.

In outlining a course of student shop-instruction, it is obvious that if the work is to be followed out on any considerable scale, it must from the manufacturer's viewpoint be more or less self-supporting; that is to say, a part of the outlay must be returned in immediate production, while the balance may be considered as to be returned at some future time through any of several channels, such as obtaining when needed with expansions of business, additional talent of a high grade for the various departments of an organization, indirect advertising of the company and its methods, future direct customers, etc., etc. In laying out such a course, it is necessary to remember that the students, upon entering, have not in many cases sufficiently matured to be able to state definitely whether they feel their talents fit them for designing, manufacturing, selling or erecting and the work in the shop must, therefore, be so arranged that they will be afforded opportunities of being brought more or less intimately into touch with the functions of these several departments, thus assisting them to reach decisions in due course regarding their relative fitness for their subsequent line of work.

During the continuance of the shop course, the student in addition to learning certain specific operations depending upon the industry entered, such as machining, bench work, assembling, winding, etc., if electrical work is being followed, is also learning many other and equally important things which will stand him in good stead all through life regardless of the profession he ultimately engages in. Chief among these may be mentioned: (1) discipline, of which the average young man can hardly get an overdose; (2) relative values of materials, methods and money, the last more especially if his home allowance is eliminated, so that he is wholly dependent upon his own earnings; (3) better appreciation of the value of his college course, as already intimated; (4) increased and quicker character development due to contact with an entirely different set of men and conditions, which contact it may be observed will work unconsciously and automatically in two directions as may be required, either by rounding off sharp corners in the strongly opinionated and self-satisfied young man or by bringing out and making more forceful the too-reserved individual.

The apprentice courses of the Westinghouse Electric & Manufacturing Company are the result of a process of evolution during the past twenty years. As at present constituted, they embody in considerable measure the composite ideas of the heads of departments, many of them college men who have gone through the courses themselves so that they have appreciated every phase of the matter, not only the needs of the apprentices but the requirements of the company. These courses were briefly described by Messrs. C. F. Scott and C. R. Dooley in their paper on ''Adapting Technical Graduates to the Industries.'' It is appreciated that while the courses are stronger in every way than formerly they can without doubt be further improved with additional experience; and this the company is fully prepared to do, recognizing as it does the almost incalculable value to be derived from them if properly developed.

REPORT OF COMMITTEE ON NECROLOGY.

OCTAVE CHANUTE.*

Dr. Octave Chanute, who was for many years one of the best-known civil engineers in this country and is noted as a pioneer in aviation, died November 23, 1910, at his home in Chicago, aged nearly 79. Mr. Chanute was born in France in 1832, the son of a professor in the College of France; and came to the United States in 1838 when his father moved to Louisiana to become vice-president of Jefferson College. The family removed to New York City in 1848, and in 1849 Mr. Chanute began his career as an engineer, and was actively engaged in that line for practically sixty years.

The professional career of Mr. Chanute is typical of that of most of the prominent engineers of this country, in that he began at the foot of the ladder. When only seventeen years of age, on introducing himself to the resident engineer in charge of the construction of the Hudson River Railroad, he was told there was "no vacancy"; but he begged for permission to serve gratis "to learn the business," and this being granted after some urging, he considered he had made his fortune when two months later he was made an assistant chainman at \$1.12½ a day. However, when he was only twenty-one years old, he was division engineer at Albany, New York, in charge of the terminal facilities and of the maintenance of way between Hudson and Albany.

In 1853 he moved to Illinois, where he worked for ten years; and as chief engineer built portions of several of the great railroads of that section of the country. During this time he was invited to submit designs of the proposed Union Stock Yards at Chicago. His plans were selected in competition with others, and later as chief engineer he built the yards much as they remained to this day. In 1866 he began the first bridge across the Missouri River, which had an ill repute and completed the bridge, a feat which established his reputation among engineers in both this country and in Europe. After this achievement and largely as the result of it, he was placed almost simultaneously in charge of the construction of four railroads in Missouri and Kansas aggregating a total of about 400 miles—a large undertaking in those days.

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* This biographical sketch was prepared by Professor Ira O. Baker.

In 1873 he became chief engineer of the Erie Railroad, a position he held for ten years, during which time the gauge was reduced to the present standard, the line was double-tracked, and the general facilities of the road were greatly improved. For a time he was in temporary charge of the motive and rolling stock in addition to his duties as chief engineer, during which time he improved the locomotives and grades so as to increase the standard through freight train from 18 to 35 cars.

While living in New York the needs of that city for rapid transit attracted Mr. Chanute's attention almost as soon as he came to live in that city. The problem had been discussed for many years without action, when he proposed that it should be investigated by the American Society of Civil Engineers. He was made chairman of the commission which he suggested; and the commission gave five months of careful study to the problem, examining all proposed schemes and conferring with many public bodies and private citizens. The report which was made public in February, 1875, advocated the building of four lines of elevated railroad to be operated by steam locomotives, and proved so convincing that the legislation needed followed almost immediately. The roads were built, and proved a great success from the very first, as everybody knows.

In 1884 he moved to Kansas City, and opened an office as consulting engineer; and in the next few years had general direction of the construction of the bridges on the Chicago, Burlington and Northern Railroad between Savanna and St. Paul, and on the Atchinson, Topeka and Santa Fe Railroad between Chicago and Kansas City.

In 1889 Dr. Chanute moved to Chicago, and continued to practice as a consulting engineer, but gave considerable time to the preservation of timber and later to the development of aviation. In 1880 he was chairman of a committee appointed by the American Society of Civil Engineers to investigate the subject of timber preservation, and the report of this committee presented in 1885 did much to bring the advantages and economics of timber preservation to the attention of engineers in this country, at a time when but little was known in this country on that subject. The report of this committee was largely his personal work, and was done so well that at its 1910 meeting the society did not consider that there was sufficient additional information available to warrant the appointment of a new committee. For many years Mr. Chanute was recognized as a leading expert on the preservation of timber.

In popular estimation the fame of Dr. Chanute will probably always rest on his work in connection with the development of aërial navigation. As early as 1874 he became interested in the science of aviation; but finding that this "side issue" interfered with his professional work, he laid it aside until 1888 when he was able to give time to it. In 1893 in connection with the Engineering Congress at Chicago he arranged a series of conferences on aërial navigation, and presented two or three papers himself. During the experiments of the Wright Brothers with flying machines from 1901 to 1905 he made at their request numerous calculations for them and supplied them with both information and advice. In 1897 he published a book entitled "Progress in Flying Machines," which contained a very concise and comprehensive account of the science and the state of the art; and in 1909 he presented a paper on "Recent Progress in Aviation" to the Western Society of Engineers. In the summer of 1910 he was awarded a gold medal by the Äëronautical Society of Great Britain. But great as was his work and influence in aviation, Dr. Chanute always regarded it as a "side issue."

Dr. Chanute contributed numerous valuable papers to the American Society of Civil Engineers; and served on several important committees in addition to those mentioned above.

had been pronounced unbridgeable, but in 1869 Mr. Chanute He was president of the American Society of Civil Engineers in 1891, and of the Western Society of Engineers in 1901. While president of the Western society he endowed three medals to be awarded for the best papers in civil, electrical, and mechanical engineering. He was a member of various scientific and engineering societies; and was an honorary member of the Institution of Civil Engineers, and of several other foreign societies. In 1905 the University of Illinois conferred upon him the honorary degree of doctor of engineering.

He was modest and unassuming, courtly in manner, extremely considerate of the feelings and opinions of others, and ever ready to help others, particularly the younger members of the profession, with suggestions or advice.

In 1893 he was chairman of the executive committee of the engineering societies having charge of the International Engineering Congress held in connection with the World's Columbian Exposition in Chicago. At one of the meetings of the chairmen of the various sections, Dr. Chanute inquired of the chairman of the section on engineering education as to progress he was making, and was informed that the chairman was greatly disappointed that the exposition company could not finance the proposed meeting, and would not be able to publish the proceedings—both of which had been promised. Dr. Chanute volunteered to lay the matter before his committee, which agreed to finance the meeting and provide for the publication of the report. The engineering societies financed the meeting, but the organization of the Society for the Promotion of Engineering Education relieved the engineering societies of publishing the proceedings of Section E of the Engineering Congress—Engineering Education. Dr. Chanute's interest at a critical time was invaluable to the Society for the Promotion of Engineering Education.

HOWARD LEE HANCOCK.*

Edward Lee Hancock was born on June 28, 1873, in Sheldsmound, Ill., and died on October 1, 1911. He graduated from the University of Wisconsin in 1898, receiving the degree of M.S. in 1902 from the same institution, following two years as an instructor. He next went to Purdue University, receiving the appointment as assistant professor in 1906, after four years as instructor. In 1909 he was chosen professor of applied mechanics in the Worcester Polytechnic Institute, and here for the past two years he has given devoted and successful service to its educational work.

He had an exceptional personality. He was always the same—friendly, agreeable, sympathetic and helpful.

> "Whose powers shed round him in the common strife,
> Or mild concerns of ordinary life,
> A constant influence, a peculiar grace."

He had all of the qualifications that go to make up the successful teacher, and called forth only the best in the students, whose interest his efforts never failed to arouse. He won the respect and esteem of everyone with whom he came in contact.

Professor Hancock's book, "Applied Mechanics for Engineers," which was first published in 1909, has been very well received, especially by those engaged in engineering education, and it has been adopted as a text book by a number of the leading engineering schools.

In 1906, in joint authorship with Professor S. E. Slocum, he wrote the "Text-book on the Strength of Materials," and his last professional work was on the proof sheets of a new edition of this book.

He was a member of the Society for the Promotion of Engineering Education; the International Association for Testing Materials, and the American Society for Testing Materials. He was a very active member of this latter association, before which he presented several papers, the last one being at the Atlantic City meeting in June of last year.

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* This biographical sketch was prepared by Professor Wm. W. Bird.

Professor Hancock was largely responsible for the working up of a comprehensive plan for the future growth and development of the Strength of Materials Laboratory at Worcester Polytechnic Institute, and as these plans are worked out, the Institute, while still mourning the loss of a faithful and reliable worker, will nevertheless continue, for years to come, to reap the benefit of his two years of devoted service to the Worcester Polytechnic Institute.

JOHN WESLEY JOHNSON.*

Dr. John Wesley Johnson was born near Pontotoc, Mississippi, April 5, 1852, and died in Chicago, August 29, 1911. From the public school near his home, he entered the University of Mississippi and was graduated with the A.B. degree in 1876, and received the A.M. degree in 1879. From 1876 to 1881, he was assistant in Latin and mathematics in the University of Mississippi. From 1881 to 1886, he was principal of the Johnson Institute at Booneville, Miss., and from 1886 to 1890 he was principal of the preparatory department of the University of Mississippi. For two years thereafter, he was a student at Leipsic, Germany, receiving his Doctor's degree in 1892. During the session of 1892–93, he was assistant professor of physics in the University of Mississippi. From 1893 to 1899, he was associate professor of physics and astronomy. From 1899 to 1906, he was professor of physics, and from the latter date to 1911, he was professor of physics and astronomy.

His death terminated a long period of service rendered the University of Mississippi. He wrought faithfully, effectively and loyally. For many years, he had much to do with the collection and management of the Alumni Loan Fund and to him is largely due the benefits which have arisen from that fund.

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* This memoir was prepared by Professor Alfred Hume.

The most valuable of his writings were on "Heat of Obscure Rays"; "Osmosis in Vegetable Membranes"; "Effect of an Electric Current on the Direction of the Spiral Winding of Morning Glory Vines."

"The distinguishing traits of Dr. Johnson's character were a peculiar and refreshing type of child-likeness of mental attitude, unshakable faith in God and in his fellow man, an entire freedom from envy and malice, an original and rather whimsical way of looking at common things, a keen sense of humor, the love of flowers, birds and children, loyalty in every relation and 'sweet reasonableness' in all things."

NATHANIEL WRIGHT LORD.*

Nathaniel Wright Lord, born at Cincinnati, Ohio, December 26, 1854, sprang from a notable ancestry. His father was Henry Clark Lord, a man prominent in the business and political life of his time, and son of Nathan Lord, for many years President of Dartmouth College; his mother, Eliza Burnet Wright, was a woman of rare vigor and ability.

Professor Lord's education was begun in the public schools of his native city, and this early training, enriched by the intellectual companionship of his parents and by a year of searching review under an exacting foreign tutor of rare gifts, was enlivened by continual boyish forays into fields of literature, history, natural history and science. This excellent and unusual preparation enabled him to enter upon and to pursue with appreciation, enthusiasm and success the rigorous course in mine engineering of Columbia College School of Mines. In this work he spent the years 1872–76, and received the degree of Engineer of Mines.

For a year after graduation he was engaged as assistant engineer in the engineering department of the city of Cincinnati, after which he accepted a position as engineer and metallurgist of the Monte Grande Gold Mining Co. of Nicaragua. While so engaged, he became seriously ill with one of the fevers of that region, which nearly cost him his life.

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* This memorial was compiled from excerpts from the faculty minutes of The Ohio State University.

Upon his return and recovery, the young engineer was appointed, November 6, 1878, state analyst at The Ohio State University. On June 18, 1879, he was appointed assistant professor of mining and metallurgy, and was put in charge of that department, which had been in active existence only a year. He was made full professor of mining and metallurgy in 1887 and his title was changed in 1891 to professor of metallurgy and mineralogy and director of the School of Mines, which title he held until his death, May 23, 1911.

Professor Lord's professional career was largely developed in the service of The Ohio State University. His earliest engineering experience as the chemist and technical director of a gold mining company in Nicaragua, though it had been of great service in developing his power and self-confidence in the application of science to engineering, yet had given him little reputation. In the new position his ability and energy were soon recognized. He became, in 1883, chemist of the Geological Survey of Ohio, contributing in addition to his chemical reports, valuable chapters on the iron industry and on the differentiation of the coal seams of the state by novel methods. His grasp of these subjects was so masterly that he became a national authority on fuels and fuel testing, and for the past eight years was chief chemist or consulting expert of the Technologic Branch of the United States Geological Survey, now the Bureau of Mines.

Upon the College of Engineering at The Ohio State University, Professor Lord has left an enduring mark. As its first dean, beginning 1896, he carried it through its formative period, and left it with policies and ideals well crystallized. His sane and practical mind rejected instantly everything that savored of show and pretense. As in his engineering, so every educational plan must rest upon a solid foundation. His constant struggle was to ground his students thoroughly—

well assured that upon such a foundation they would erect a secure superstructure. His teaching was a constant appeal to the reason, and to the constructive imagination. To see him with a class attack a problem new to both, was a rare experience.

Combined with his power and inspiration as a teacher, was his pre-eminent ability as an investigator. The training of the chemical laboratory, where everything must be accounted for, gave to his naturally incisive thinking processes, a precision and analytical power most unusual. No man could with more unerring certainty strip a complicated problem of its disguises and lay bare its fundamental principles. No field of science upon which he touched failed to profit in some enduring way from his ever active mind.

No man could associate with him in any capacity without admiring him: his large mind and generous spirit had no room for anything little or sordid. Creditable, useful, even brilliant, as many of his contributions to science and engineering have been, his influence on his students and on his colleagues is the signal proof of his greatness.

To the very last he was a man of diversified interests and continually entered upon new pursuits with characteristic enthusiasm.

Professor Lord was a man of marked intellectual vigor. His mind was no less judicial than analytical. He thought clearly and spoke with logical precision. In action he was prompt, decided and fearless. His moral convictions rested upon reason rather than upon authority or tradition.

With the reserve of a gentleman who permitted no undue familiarity, he yet remained essentially democratic, and no one felt humbled in his presence. Honesty was fearless before him. To those who won his confidence, he was a loyal friend and a wise counsellor.

STILLMAN WILLIAMS ROBINSON.*

Stillman Williams Robinson, emeritus professor of mechanical engineering, died on Monday morning, October 31, 1910.

Professor Robinson was born on a farm near South Reading, Vt., March 6, 1838. His early life was that of a country boy, but his love of mechanics led him to the shops and he served a four-year apprenticeship to the trade of machinist.

He earned the money to defray the expenses of his early education and to prepare himself for college. In 1860 he left home to attend the University of Michigan. He made the journey largely on foot and met his expenses by working as a machinist on the way and arrived at Ann Arbor with fifty dollars more than the eight with which he started.

He graduated from that university in 1863 with the degree of civil engineer, having supported himself through his college course by his skill as an instrument maker, in particular graduating thermometers. This led to his first invention, made while in college, of a machine for graduating such instruments. Notwithstanding the difficulties under which he labored, he earned the reputation of a brilliant and original student.

After graduation, he entered the government service as assistant engineer in the U. S. Lake survey, remaining in that service until 1866, when he returned to the University of Michigan as instructor in engineering.

He left the University of Michigan in 1870 to become professor of mechanical engineering and physics in the Illinois Industrial University, now the University of Illinois. There he established the Department of Mechanical Engineering which was the first to be established in this country.

It is of interest to note as illustrating his versatility that while there he designed and constructed the tower clock now furnishing time at the University.

In 1878 he occupied the position of dean of the College of

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* This biographical sketch was prepared by a committee consisting of Professors N. W. Lord, Edward Orton, Jr., and Wm. T. Magruder.

Engineering at that institution. The same year he was called to The Ohio State University as professor of physics and mechanical engineering, occupying that chair until he resigned in 1895 in order to devote his time to his extensive professional interests. In 1896 in consideration of his distinguished services as a scientific inventor, investigator, and writer, the Ohio State University conferred upon him the degree of doctor of science and in 1899 elected him emeritus professor of mechanical engineering.

Professor Robinson was a man of great originality and inventive genius. He secured about forty patents, many of which were based upon scientific research and mathematical investigation, the results of skillful study. They were designs rather than accidental discoveries. He was also the author of important books and papers presented before learned societies which are marked by the same quality of thorough research and originality. When the Ohio gas fields were first discovered the problem of measuring the volume of flow was referred to Professor Robinson and solved by him in his brilliant application of the Pitot tube, resulting in the methods now in universal use.

His interest in education was always great and led him in 1890 to organize an association composed of mechanical engineering teachers which in 1893 developed into the present Society for the Promotion of Engineering Education. His interest and love for the University did not cease with his retirement. He made at various times valuable donations to the equipment of the department of mechanical engineering and finally established the Robinson Fellowship in Engineering as a permanent foundation.

As a man, Professor Robinson was an indefatigable worker. There was no limit to his enthusiasm and ambition in his profession. Personally he was modest and retiring, never claiming credit for himself though most generous in according it to his associates. His nature was deeply sympathetic and very kindly. He was inflexible in his devotion to his duty and to his principles of integrity and honor. He was greatly interested in the work and success of those around him, both colleagues and students, and impressed his own enthusiasm upon their efforts, encouraging, stimulating and rewarding them. His memory and influence will long be felt in the lives of those who follow after him and have taken up his work where he left it.

JOHN ARMOR VEAZEY.*

Mr. John Armor Veazey was born June 23, 1880, at Emsworth, Pa. His early life was spent with his parents at Chase City, Va., where his father was in charge of a mission school. He was graduated from Westminster College, at New Wilmington, Pa., in 1902, receiving the degree of A.B. From 1902 to 1905 Mr. Veazey was an instructor in physics and astronomy at Assiut College, Assiut, Egypt. He entered Cornell University in the fall of 1905 and received the B.S. degree in 1906; he served as an instructor in the Department of Physics at Lehigh University, 1906–08. Mr. Veazey was a graduate student at Cornell University, 1908–11, and received the degree of Ph.D. in June, 1911. At the time of his death he was under appointment of the Carnegie Endowment, to do original research work in the department of physics of Cornell University.

Mr. Veazey was united in marriage to Miss Martha Mehard, of New Wilmington, Pa., on August 24, 1910. While on a vacation at New Wilmington, Mr. Veazey was stricken with typhoid fever. After an illness of two weeks pneumonia developed, resulting in Mr. Veazey's death on Monday morning, August 21, 1911.

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* This biographical sketch was prepared by Professor B. W. Bridgman.

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